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The works of the Lord are great, sought out of all them that have pleasure therein.—Ps. cxi, 2.

THE SIDEREAL MESSENGER.

MARCH, 1890.

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DIRECTOR OF CARLETON COLLEGE OBSERVATORY.

NORTHFIELD, MINN.

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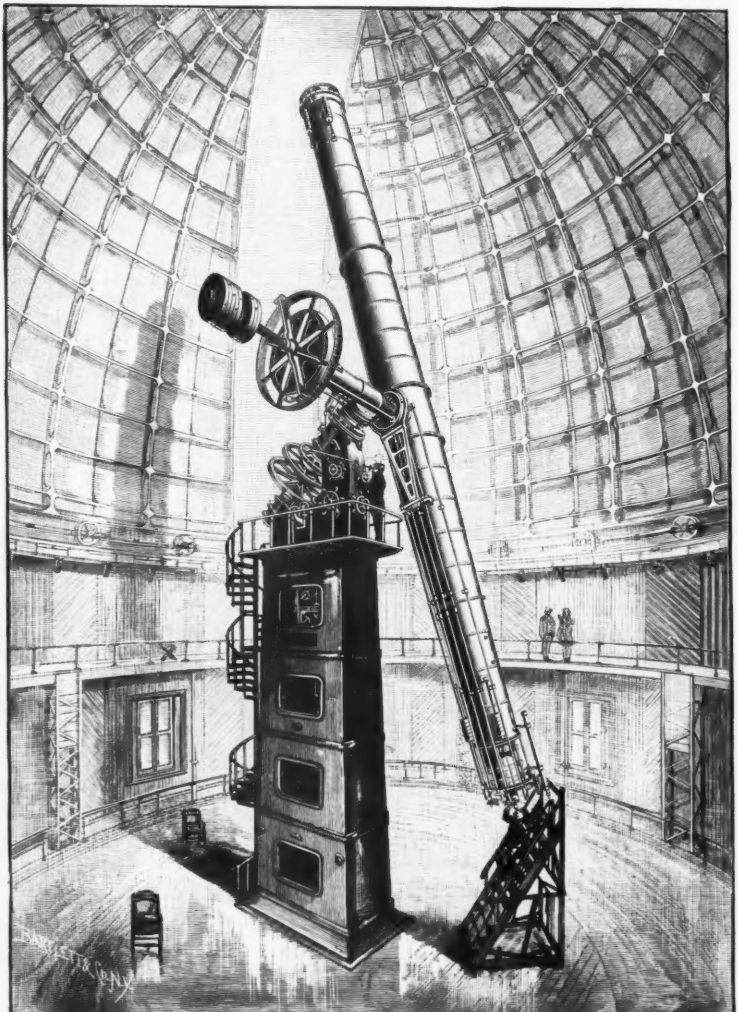

WARNER & SWASEY,
DESIGNERS AND BUILDERS.

OBJECT GLASS BY
ALVAN CLARK & SON.

THE LICK TELESCOPE.

LENGTH 57 FEET. DIAMETER OF OBJECT GLASS 36 INCHES.
TOTAL WEIGHT 40 TONS.

THE SIDEREAL MESSENGER,

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 9, No. 3. MARCH, 1890. WHOLE No. 83

THE GREAT TELESCOPE OF LICK OBSERVATORY.

To answer many queries that come to us from time to time from interested readers of THE MESSENGER, we have collected and give below, the principal facts concerning the equatorial telescope of Lick Observatory, which is now the largest and most powerful instrument of its kind in the world. Many of these facts have appeared in print before, but they are repeated in connection with some new ones, that the general reader may have at hand a brief and concise statement of them for ready reference.

By kindness of Messrs. Warner & Swasey, Cleveland, Ohio, we are able to give a fine cut of this great telescope for frontispiece to this number.

This noble instrument was completed in 1888, and placed on Mt. Hamilton, Santa Clara County, California, which is fifty miles southeast of San Francisco, and twenty-six miles east of San José. The elevation of the site above sea level is 4,209 feet and it commands a view of the southern end of the San Francisco Bay.

A few of the prominent features of the mounting of this telescope may next be named. The column is of cast iron 10 × 17 feet at the base, and 4 × 8 feet at the top, and weighs 20 tons. On this rectangular column rests the head, weighing 4 tons, into which is journaled the polar axis. Around this head is a balcony on which the assistant astronomer is stationed. By a system of wheels he is able to adjust the instrument for the study of any celestial object desired, and to read positions by microscopes illuminated by electric lights. The polar axis is made of steel, 12 inches in diameter, 10 feet long, and weighs 2,700 lbs. The declination axis is also of steel 10 feet long, and weighs 2,300 lbs. The tube is of steel, 57 feet long; its diameter being 4 feet at the center and 38 inches at the ends.

The tube complete with its attachments weighs 5 tons, and its motion in following a star is controlled by a driving clock which weighs one ton, and which is placed within the column and near its top, and within easy reach from a landing of the spiral staircase. The center of motion of the tube is 37 feet above the base, and when the telescope is pointed to the zenith the object glass is 65 feet above the base of the column. At the side of the great tube three telescopes are attached of apertures respectively 6, 4, and 3 in., which serve as finders. When the instrument is turned in declination the weight of the part of it in motion is 7 tons. When moved in right ascension the weight of moving part is 14 tons. The total weight of this great telescope is 40 tons.

The object glass was made by Alvan G. Clark, Cambridgeport, Mass., and has a clear aperture of 36 inches, a focal length of 627 inches and weighs in its cell 532 lbs. One second of arc at the focus is therefore about $\frac{3}{1000}$ of an inch, and the image of the sun at the focus is 6 inches in diameter. The photographic corrector is a lens of 33 inches clear aperture with a focal length of 550 inches. The photographic image of the sun is therefore $5\frac{1}{10}$ inches in diameter. Upon these images much work is done by the astronomer by the aid of special accessories such as the spectroscope, micrometer, photographic apparatus, etc.

The magnifying power which this instrument carries ranges from 180 to 3,000 diameters. Professor Holden has remarked on this point that, "While the magnifying power which can be successfully used in a five-inch telescope is not more than 400, the 36 inch telescope will permit a magnifying power of more than 2,000 diameters on suitable objects, stars for example. This power can not be used on the moon or planets with real advantage for many reasons, but probably a power of 1,000 to 1,500 will be the maximum. The moon will thus appear under the same conditions as if it were to be viewed by the naked eye at the distance of say 200 miles. This is the same as saying that objects 300 feet square can be recognized. So that no village or great canal, or even large edifice can be built on the moon without our knowledge. Highly organized life on the moon will make itself known in this indirect way if it exists."

We have just received "Notices from the Lick Observatory," prepared by members of the staff, in which appear an abstract of a paper by Mr. Keeler on the *Efficiency of the Great Equatorial*, which is given here in full as follows:

EFFICIENCY OF THE GREAT EQUATORIAL.

The following extract from a paper by Mr. Keeler summarizes the opinions of the astronomers of the Lick Observatory upon the performance of the great telescope, and may be of general interest:

. . . "As the large telescope has now been sufficiently long in use for a thorough test of its various qualities, it may be worth while to give a brief summary of the different kinds of work in which it has proved to be effective.

"*Separation and measurement of close double-stars*, as attested by the long list of new doubles, and micrometer measurements of these and of difficult pairs already known, published by Mr. Burnham.*

"*Detection of very faint stars.* Professor Holden and Mr. Schaeberle have observed six stars within the dark interior space of the ring nebula in Lyra, besides the central one (No. 14 of Lassell's drawing), and five more within the nebulosity,† and of all these, only the central one was previously known. An example of a double-star with extremely minute components discovered with this telescope, is the pair preceding the trapezium in the nebula of Orion.‡ It was found by Mr. Barnard; and Mr. Burnham, who measured it, considers it the most difficult pair with which he is acquainted in the whole heavens.

In this connection may also be mentioned the observations of the satellites of Mars,§ made here during the opposition of 1888. When Mars was in opposition the satellites were easy objects, being plainly visible without the aid of an occulting bar to hide the planet, and they were seen as late as July 18th, when their brightness was only 0.12 of that of their discovery in 1877.

"*Observations of the structure of the nebulæ.* The Lyra nebula has already been mentioned under the preceding

* *Astronomische Nachrichten*, (Nos. 2929 and 2930).
† *Monthly Notices*, R. A. S. (Vol. XLVIII, No. 383).
‡ *Monthly Notices*, R. A. S. (Vol. XLIX, No. 6).
§ *Astronomical Journal*, (No. 178).

division, but only in relation to the minute stars which appear in it. The structure of the nebula itself was better seen by Professor Holden with this instrument than with any other that he had used. He says: 'One's first idea is not so much that the aspect is unfamiliar as that it is distinctly different; that its simple structure has suddenly become complex; and, finally, that the task of depicting it completely is practically impossible by the ordinary methods.'* The observations which show the probable existence of helical forms in the nebulæ† should also be mentioned.

"*Observations of comets.* The companions of Brooks' comet have been observed and measured during the past few months by Mr. Barnard, who finds a considerable advantage in the thirty-six-inch over the twelve-inch refractor.‡ With the latter instrument the faint companions, called by Mr. Barnard *D* and *E*, were at all times invisible, although for blackness of field and excellence of definition the twelve-inch telescope is unsurpassed.

"*Definition of the surface features of a planet.* The views of *Jupiter* obtained here during the past opposition have sufficiently proved to all the observers that the large telescope is as suitable for the observation of planetary details as for the other classes of work above given. The extremely fine division, discovered by the writer, in the outer ring of *Saturn*, out side of the Encke shading,§ has been seen by all the observers here on numerous occasions, but, so far as I am aware, it has been seen at no other place. Finally, I may refer to observations by Professer Holden, not yet published on details seen in specially interesting parts of the lunar surface.

"These different classes of astronomical work essentially cover the field of visual observation,'and in all the thirty-six-inch refractor has shown its capability of yielding the best results."

The possibilities of this instrument, by the aid of its photographic apparatus, are probably very much greater; but how much greater we are not yet able to say, as the instru-

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* *Monthly Notices* R. A. S. (Vol. XLVIII. No. 9, p. 385).

† *Publications* of the Astronomical Society of the Pacific, (No. 3), and *Himmel und Erde*, (October, 1889).

‡ *Astronomische Nachrichten*, (No. 2919).

§ SIDEREAL MESSENGER, (No. 62); *Astronomical Journal*, (No. 190); *Ciel et Terre*, (2e serie, t. V, 1889.)

ment, so far as we know, has not yet been put to a full and general test of its powers in the varied field of difficult photographic work.

THE PROGRESS OF ASTRONOMY IN 1889.

At the beginning of this, the last decade of the century, we propose, according to our annual custom, to furnish a short précis or chronicle of the astronomical occurrences of the year just departed; and to put on record such observations, discoveries, investigations, and events as concern the history and progress of astronomy generally.

The year 1889 opened with a phenomenon of high astronomical interest, the total eclipse of the sun on January 1st, which was most excellently observed in California. Particularly successful were a large proportion of the very numerous photographs of the corona obtained by the various parties of observers, and among them those secured by the party from Harvard College Observatory, under the direction of Professor Pickering; the ones taken by Mr. Barnard, of the Lick Observatory; the negatives obtained by the party from Washington University (St. Louis); and last, though by no means least, those of the Amateur Photographic Association of the Pacific Coast, under the able direction of Mr. Charles Burckhalter. The result has been entirely to corroborate the theory that, during the period of sun-spots, the corona undergoes a series of characteristic and typical changes. Incidentally we may mention that Mr. Keeler, of the Lick Observatory, also demonstrated the untenability of the hypothesis of Professor Hastings that the corona is a phenomenon of diffraction.

Careful preparations were also made for the effective observation of the total eclipse of the sun, which occurred during the morning of December 22. Two expeditions were organized by the Royal Astronomical Society. The members of the first, the Rev. S. J. Perry, F. R. S., and his assistant, Mr. Rooney, proceeded to the Salut Islands. Mr. Taylor went alone, on the second, to Loanda. An American expedition, headed by Professor D. P. Todd, was also dispatched to Angola by the Navy Department at Washington; while two

of the Lick observers went to Cayenne. Miss E. Brown and Miss Jefferies were to view the eclipse from Trinidad. Up to the moment of our writing, the sole news which has reached this country from any of those whom we have mentioned has taken the shape of a telegram from Mr. Taylor, unhappily announcing his own total failure to see anything of the phenomenon which he had travelled so many thousands of miles to witness. We can only express our earnest hope that other observers may have been more successful.

The occultation of Jupiter by the moon in the evening of August 7 was successfully observed at numerous stations. Curious effects of shading on the planet's limb, and adjacent to that of the moon when she crossed Jupiter's disc, were seen by a large number of those who witnessed the occultation.

The conjunction of Mars, Saturn, and Regulus during the early morning of September 20 was looked forward to with considerable interest, as calculated to shed light upon the nature of certain pre-telescopic observations of planetary conjunctions; but, unfortunately, our wretched English climate rendered its observation practically impossible over nearly the entire kingdom.

On March 6, that well-known observer, Dr. Terby, of Louvain, noticed a white spot on Saturn's rings contiguous to the shadow of the ball. This was also seen by Mr. W. R. Brooks at Geneva (New York), subsequently. *Malgre*, however, the concurrent testimony of two such competent astronomers, there can be little or no doubt that the appearance was a wholly subjective one, inasmuch as it was invisible in such enormous and powerful instruments as the mighty Lick refractor and Mr. Common's famous five-foot reflector.

We referred last year (Vol. XLVIII. p. 368) to the researches of Mr. Crew on the solar rotation period. To meet certain objections to the method he employed, he has repeated his observations, after taking special precautions against the heating of the jaws of the slit of his spectroscope. His final results are sufficiently startling, giving as they do a period of 26.23 days as that occupied by the sun in turning on his axis, against the 24.79 days of Carrington

and Spöerer. But the question can in no sense be regarded as settled.

It has been erroneously supposed that the question of the possibility of photographing the corona of the uneclipsed sun was disposed of by Dr. Huggins's failure to obtain good negatives in 1886; but there can be no doubt that the absence of an absolutely clear sky in England (save on the very rarest possible occasions) may be held to explain this. On April 12th, 1888, however, he did succeed in obtaining a photograph which if it does not really exhibit the corona, is a marvelous example of an optical illusion. His method is to be tried in the diaphanous atmosphere of Athens by Eginitis, the astronomer in charge of the Observatory there; and experiments were probably made also by one or more of the observers in the eclipse of December 22.

A question which has excited some discussion has been finally set at rest by the joint investigations of Dr. Huggins and his gifted wife. It must be familiar to many who will read these lines that Mr. Lockyer insisted that the chief line in the spectrum of the great nebula in Orion was simply the edge of a fluting of that of magnesium at a comparatively low temperature. Dr. and Mrs. Huggins have now shown conclusively that this is an entire mistake, and that this line belongs to some, so far, unknown body. The researches of Dr. Huggins on the principal line of the auroral spectrum have also had the effect of correcting another mistake of Mr. Lockyer's; that gentleman having referred it to the brightest fluting of manganese at wave-length 5580; while Dr. Huggins, with the most perfect apparatus employed with that skill which has earned him such imperishable renown, has finally determined its wave-length to be 5571.5. Lastly, it was suggested by Mr. Lockyer that the dark bands seen in the spectrum of Uranus by Huggins, Secchi, Vogel, etc., were merely spaces between the flutings of a radiation spectrum. Mr. Keeler, of the Lick Observatory, employing the giant 36-inch telescope, finds that the bands are actual absorption ones, and could see that the spectra of the satellites Oberon and Titania were continuous!

The remarkable researches of Professor Pritchard in Stellar Parallax, by means of photography, have been continued during 1889, and the results so far obtained were published

some two months since, in Vol. III. of the "Astronomical Observations made at the University Observatory, Oxford." They shed a new light upon the physical structure of the visible universe.

Commencing in 1884, and working on every available occasion since, Dr. Boeddicker, Lord Rosse's assistant astronomer, has produced a series of drawings of the whole of the Milky Way visible in these latitudes, which is as unsurpassed as it is probably unsurpassable in the elaborate character of its minute detail. It is verily a marvel of the most minute and patient accuracy, and cannot fail materially to advance our knowledge of the fabric of our stellar system. Dr. Boeddicker's astonishing drawings are deposited in the library of the Royal Astronomical Society, until some effectual means can be devised for their reproduction.

Seven Comets have been discovered during the year which has just closed. The first (*a*) was found by Brooks at Geneva, N. Y., on January 15th; the next (*b*) by Barnard, at Lick, on March 31st; the third (*c*) also by Barnard, on June 23rd; the fourth (*d*) by Brooks, on July 6th; the fifth (*e*) by Davidson, at Melbourne, on July 21st; the sixth (*f*) by Lewis Swift, on November 17th; and the seventh (*g*) by Borrelly, at Marseilles, on December 12th. None of these objects attained to any conspicuous brilliancy, the only circumstance worthy of note in connection with them being that Brook's Comet (*d*) divided into two parts.

By a coincidence, seven is also the number of Minor Planets picked up in 1889. To Palisa belongs the credit of finding the first (282) on January 4th; Chairlois discovered 283 on January 28th; 284 on May 29th; and 286 on August 3rd; Palisa picking up 285 on the same day. Peters found 287 on August 25th, since which there has been a lull in these absolutely useless discoveries.

In connection with the Bibliography of Astronomy, we must place that admirable work, Young's "General Astronomy," at the head of our list, as the most worthy successor to Sir John Herschel's "Outlines" that has yet appeared. Students of planetary detail will find much of a most instructive nature in Boeddicker's "Observations of the Planet Jupiter," Green's "Belts and Markings of Jupiter, and very

notably in that remarkable and exhaustive book "Zenographical Fragments," by Mr. Stanley Williams. Two works, each of high interest in very different ways may be commended to those interested in physical astronomy, they are "Elementary Theory of the Tides," by Abbott, and "Time and Tide," by the Irish Astronomer Royal, Sir R. S. Ball. The first treats the theory of the tides mathematically, but in a simple, apprehensible, and what is of grave importance, absolutely correct form. The second, a popular exposition of Prof. G. H. Darwin's researches, is as interesting as a good novel. The first volume of the new edition of Chambers's "Handbook of Astronomy," has recently appeared. As has been observed by one of our own correspondents this has now become a veritable encyclopedia of the science, and almost indispensable as a book of popular reference. Nor must we omit Mr. Cottam's splendid "Charts of the Constellations," than which nothing finer of the kind has ever appeared.

Death has happily claimed but few distinguished Astronomers as his own during the late year. The first to pass away was Dr. Warren de la Rue, who will long be remembered as the pioneer in English astronomical photography; as a skilled practical observer; and as a man who, both in purse and in person, was unsparing in the promotion of astronomy. He furnished a bright example of a class (erroneously supposed to exist only on the other side of the Atlantic) who munificently devote no inconsiderable portion of their fortunes to the advancement of science. Mr. R. S. Newall, who died within a very short time of Dr. de la Rue, was less known as an astronomer than as the possessor of a very big telescope. This has, it is understood, been presented to the University of Cambridge, who are to house and employ it. We last year announced the retirement of Miss Maria Mitchell from the Professorship of Astronomy at Vassar College, New York. She died in July, 1889. Professor Cacciatore also died at Palermo in the same month. Earlier in the year Wilhelm Tempel, of Florence, after a protracted illness, was taken. One of the most familiar names among those who have joined the majority is that of Professor Elias Loomis, whose "Practical Astronomy" is to be found probably in every Observatory in which the English

language is legible. His somewhat less familiar "Treatise on Astronomy" forms a model work of reference.

Among miscellaneous astronomical facts and occurrences may be mentioned the appointment of Dr. Ralph Copeland as Scottish Astronomer Royal, and the projected erection of a new and efficient Observatory in the outskirts of Edinburgh. The founding and rapid rise of the Astronomical Society of the Pacific tends to remind us of the allied success of the Liverpool Astronomical Society in this country. The Californian institution, however, possesses the enormous advantage of its intimate connection with the Lick Observatory on Mt. Hamilton, the results of the work at which it has the privilege of making public through its Transactions. We may also notice the removal bodily of the Observatory and instruments of our great astronomical photographer, Mr. Isaac Roberts, from the dingy, cloud-laden atmosphere of Liverpool to the clearer sky and considerable altitude of Crowborough Beacon in Sussex. All familiar with the marvellous results obtained by Mr. Roberts under every possible meteorological disadvantage, will look forward with eager hope to his future triumphs under more favorable conditions. An elaborate remeasurement of the French Arc of the Meridian, completed as far as actual instrumental observations were concerned in 1888, has been to a great extent reduced during the past year. It differs by less than $\frac{1}{300000}$th from the results of the English, Belgian, Italian and Spanish triangulations—a striking illustration of the precision of modern methods of observation. Incidentally a redetermination of the difference of longitude between Dunkerque and Greenwich has been effected but the final result has not as yet been made public.—*English Mechanic, Jan. 3, 1890.*

ASTRONOMICAL SOCIETY OF THE PACIFIC.

CHARLES BURCKHALTER, SECRETARY.

FOR THE MESSENGER.

The meeting of the Astronomical Society of the Pacific Jan. 25, 1890, was held at its rooms in San Francisco. President Holden was unable to be present on account of

the storm and ill health. Mr. Keeler came from the Observatory on Mt. Hamilton purposely to attend the meeting, walking seven miles of the distance through the snow which was five feet deep in places. In the absence of President Holden, Vice President Pierson presided. The meeting was largely attended.

The secretary read a list of seventy-five presents of books, etc., calling attention to two large drawings of Jupiter twenty-eight inches in diameter. The thanks of the Society were voted to the donors.

The chair announced the success of the eclipse party of the Lick Observatory which was sent to South America at the expense of Col. C. F. Crocker. It was also announced that the Board of Directors had, with the approval of Alexander Montgomery, determined to expend $1,000 of the Alexander Montgomery Fund to found a library, to be known as the Alexander Montgomery Library of the Astronomical Society of the Pacific, and that the remainder of the fund ($1,500) should be invested and the income only to be used in preserving and enlarging the same.

Twelve new members were elected, as follows:

W. Steadman Aldis, Auckland, New Zealand; Jose A. y Bonilla, Zacatecas, Mexico; A. R. Church and Hugh Howell, Oakland, Cal.; Mateo Clark, London, England; Levi K. Fuller, Brattleboro, Vt.; Frederick G. Wattles, Denver, Col.; Professor M. W. Harrington, Director Ann Arbor Observatory, Ann Arbor, Mich.; Professor Ira More, Los Angeles, Cal.; T. S. Palmer, Washington, D. C.; James L. Scott, Shanghai, China; P. V. Veeder, D. D., San Mateo, Cal.; Adolph Sutro, San Francisco, Cal. Messrs. Clark and Sutro were made life members.

Mr. James E. Keeler then read a paper "On the Physical Observations of Jupiter in 1889," in which Mr. Keeler exhibited a series of twenty-four drawings of Jupiter, made during the opposition of 1889, with the thirty-six-inch equatorial of the Lick Observatory. The drawings were made on a large scale, the elliptical outline of the planet being 3.50 × 3.30 inches, and were intended to show all the details that could be perceived with the telescope and transferred to paper in the limited time allowed by the rotation of the planet (about fifteen or twenty minutes). All dimen-

sions were mere eye-estimates, but they had been checked by micrometer measurements, and found to be fairly accurate. Reference was made to the extremely satisfactory views obtained with the great telescope and a *resume* given of the different kinds of astronomical work in which the instrument had proved to be efficient.

The equatorial zone of Jupiter was brilliant white at the edges, with a salmon-pink central stripe, which the measurements showed to be a trifle south of the equator. From the edges of the zone long streamers projected at certain places into the red belts, with which they eventually became parallel, and gradually becoming more diffuse, were lost in the general red color of the background. These streamers which are doubtless the cause of the double and triple red belts, often described, were, according to the observations, masses of clouds projected outward from the equatorial zone, and gradually left behind by the forward drift of that region. Two were frequently seen abreast, but never three. The roots of the streamers were never brighter than the average surface of the equatorial zone, and were usually tinged with a curious olive-green color, which seemed to be characteristic of great disturbance. At certain parts of the equatorial zone, the streamers were sometimes considerably distorted, but when long they invariably pointed toward the following limb of the planet. Observations of bright knots on the streamers showed that there was a flow of matter along them from the root outward.

The red spot was frequently well seen. It was shorter than in 1881. The color was a pale pink, lighter in the middle of the spot. At the following end the outline was marked by a faint dark shading.

On a broad, uniformly tinted, gray belt on the southern hemisphere, following the red spot, were many oval and round brilliant white spots, forming one of the most beautiful features of the surface of Jupiter. A curious symmetry was often observed in the grouping of these spots, which are shown in nearly all the drawings.

On the northern hemisphere the details were much simpler, and the belts were of the usual form. Bright white spots like those described above were never seen. As in former

years the greatest activity seems to be manifested south of the equator.

This was followed by a paper entitled "A New and Simple Form of Electric Control for Equatorial Driving Clocks," also by Mr. Keeler. This ingenious contrivance is attached to the driving clock of the great refractor of the Lick Observatory, and is giving great satisfaction.

A committee was appointed to nominate a ticket to be voted for at the annual meeting (March 29th).

The meeting then adjourned to March 29th.

THE RELATIVE ACTIVITY IN THE TWO SOLAR HEMISPHERES.

EDWIN B. FROST.*

FOR THE MESSENGER.

Professor Spoerer called attention in Astronomische Nachrichten, No. 2887, to the difference in the activity in producing spots of the two solar hemispheres between 1883 and 1888, and Professor Riccò of Palermo followed, in No. 2919, with a similar discussion of the prominences. It appears that spots have been much more numerous in the southern hemisphere, the ratio being 20 : 11 for the whole period, while the separate ratios for 1887 and 1888 were much larger being 2.3 : 1 and 3.4 : 1 respectively.

From observations on 203 days in 1889, using the 9.4-inch equatorial and a projected image of 8 inches diameter I obtain the following results:

Northern Hemisphere,	6	groups,	24	spots,	mean latitude of spots	$+\ 9^\circ.6$
Southern "	18	"	98	"	" " " "	$-14^\circ.5$
Total	24	"	122	"		

The preponderance of spots in the Southern Hemisphere has thus continued during the past year, and with a slight increase, the ratio for spots being 4.1 : 1 and for groups 3 : 1.

The period of this swing in activity from one hemisphere to the other, if it can be said to be truly periodic, does not seem to be determinate from the data at present available. The mean latitude of spots, which since 1879 has been

* Director of Shattuck Observatory, Dartmouth College, Hanover, N. H.

steadily decreasing, has increased during 1889,—an indication that the minimum is very nearly, if not quite passed. Dr. Spoerer gives for the mean latitudes in 1888 $+ 5^\circ.9$ and $- 6^\circ.9$, and the Greenwich observations $+ 7^\circ.1$ and $- 7^\circ.5$. The values which I give above, $+ 9^\circ.6$ and $- 14^\circ.5$, are the means of the latitudes of the chief spot of each group, which may be assumed to represent on the whole the mean latitudes of all the spots.

The conclusion of a period of minimum activity is also generally signalized by the appearance of spots in high latitudes. On June 30th and July 1st, I observed a small spot in the remarkable latitude south 42°; this spot was elsewhere observed in Europe, but was overlooked on the Greenwich photographs until Father Perry called attention to it. On October 22 I saw a faint dot, which possibly ought to be classed as a veiled, rather than a true, spot in north latitude about 51°.

From observations of the whole circumference of the sun on 83 days in 1889. I find a preponderance of prominences (none under 20″ in hight being included) in the Southern hemisphere, similar to that in the case of spots.

The distribution in latitude is as follows:

	North.	South.		North.	South.
80° — 90°	5	2	30° — 40°	6	21
70° — 80°	1	4	20° — 30°	10	12
60° — 70°	3	6	10° — 20°	7	15
50° — 60°	8	8	0° — 10°	6	10
40° — 50°	11	18		—	—
			Totals	57	96

A distinct maximum is shown between 30° and 40° south; the mean latitude of northern and southern prominences falls between 30° and 40°, that for the northern being slightly the greater.

The ratio of southern prominences to northern is 1.68. It is proper to say that the position angles, from which the latitudes are deduced, have not been directly measured but have been estimated with the aid of the position circle of the telescope.

Professor Riccò's tables show that prominences have been most abundant in the southern hemisphere since 1884, with the single exception of '86; the ratio of southern to northern prominences he found to be for 1888, 3 : 1.

The small value, 1.84, of the mean number of prominences per observation indicates that the chromospheric activity is also near a minimum.

Further evidence of this is given by the quiescent character of the prominences, which have been found almost invariably of the diffuse hydrogen type. The largest one seen was visible on four days, Nov. 15-18, in S. lat. 49°, and remained at an altitude of about 100.″

DARTMOUTH COLLEGE, Hanover, N. H., Feb. 5, 1890.

TRANSIT OBSERVATIONS BY PHOTOGRAPHY.

WILLARD P. GERRISH.

FOR THE MESSENGER.

A paper read by Mr. W. E. Wilson before the Royal Astronomical Society at its meeting, December 13, 1889, calls attention to a device for taking transit observations by photography. It may be of interest to note that experiments were made at Harvard College Observatory as early as January, 1886, on the plan proposed by Mr. Wilson. Photographs were made of the Pleiades with the eight-inch Bache telescope with view of determining the degree of accuracy with which time could be determined. The star images were allowed to trail over the plate, the telescope remaining at rest. Exposures of different lengths were given and the images were afterward measured. The discussion showed that a single setting on an image made by an exposure of one second could be made with a probable error of only $0^s.03$. An account of this work can be found in Memoirs of American Academy, Vol. XI, p. 218.

The subject was again taken up in the summer of 1888 and experiments were continued by Professor F. H. Bigelow and the writer. A photographic plate was attached to a common telegraph sounder and placed at the focus of a six-inch telescope. The plate was moved with an alternating motion at intervals of one second in a plane perpendicular to the axis of the telescope. The direction of this motion was parallel to the meridian. The star image was allowed to trail across the plate by the diurnal motion. Two rows of dots were thus formed, each dot representing one second of time.

After these preliminary experiments Professor Bigelow constructed an experimental apparatus more especially adapted to the work. This was used with the same telescope and gave very good results. It was fitted with a small plate holder which was connected with the armature of a magnet by which the motion was imparted. A reticule of raw silk fibres was placed at the focus of the telescope, and an impression of this reticule was made on each plate by throwing the light of a lantern into the objective for an instant, slightly fogging the plate. The wires appeared as distinct light lines on a slightly darkened background, though not sufficiently dark to obscure the star images. An attempt was made to operate the instrument directly from the sidereal clock of the Observatory. The clock has an ordinary break-circuit attachment, and the signal was found to be of so short duration that it made no appreciable break in the star trail.

In the autumn of the same year a complete set of apparatus of fine workmanship was constructed from the plans of the writer. It consists of two separate and independent instruments, one being designed to transform the signals of an ordinary clock into alternating signals, and the other being a small tail-piece carrying the magnet and mechanism to be attached to the transit instrument.

The alternating machine is not unlike an ordinary telegraph relay in appearance. A large magnet in the circuit of the standard clock actuates an armature lever which has at its upper end a pawl engaging the teeth of a ratchet wheel. The wheel moves one tooth at a time with each movement of the armature and turns a contact wheel. Upon this rests a spring completing a local circuit operating the mechanism on the telescope. Alternate sections of the contact wheel are cut away, so that the local circuit is alternately opened and closed with each signal on the clock circuit. A second contact wheel on the same arbor with the first is cut away, to give signals of two seconds duration, for use on northern stars where the one second interval would make the images too near together. A switch serves to send the local current through either of these at the will of the observer.

The tail-piece consists of a brass box 4 inches long, 2½ inches wide, and 1⅜ inches deep, weighing with its contents and attachments 17½ ounces. It has on its side an opening

which fits the adapter of the telescope. In this box is a small electro-magnet, to the armature of which is attached a small, square photographic plate measuring 1¼ inches on a side. The plate is held in position by a spring clamp which prevents any accidental slipping. The plate has a motion of about 0.01 inch, the amount being regulated by two adjustable stops between which the armature vibrates. The frame, or clamp, carrying the plate is hung on a system of parallel levers similar to a parallel ruler, and so arranged that it can move only in a direction parallel to the meridian. All of the bearings are hardened steel points, fitted with springs to take up all lost motion and to prevent the plate from changing its position after having been once adjusted. An important feature of this portion of the apparatus is that the plate is clamped directly to the armature lever of the magnet, without the interposition of a plate holder. This greatly reduces the chance of error from the slipping of the plate. As the reticule is rigidly and permanently attached to the telescope, it is only necessary that the plate should remain accurately in place during the observation until the impression of the reticule is finally made upon it. The brass box serves as a plate holder, being so small and light that it can readily be detached and carried to the dark room to be recharged with a fresh plate. A small slide which covers the opening in the box serves to exclude the light when it is detached from the telescope.

A small three inch transit instrument was chosen for the work and the apparatus was fitted to it. Observations were made on several of the brighter stars, but owing to the small aperture of the telescope, stars fainter than the third magnitude could not be taken. An instrument for use with the device should have a very large angular aperture.

OBSERVATORY LOCAL PATRONAGE

LETTER FROM PROF. H. S. PRITCHETT.

Editor of the Sidereal Messenger:

In your February number appears a communication from Capt. Phythian, U. S. N., Superintendent of the Naval Ob-

servatory, in which two personal letters of mine are printed. I do not think that the personal part of Capt. Phythian's letter calls for a reply from me, further than to say, that I had nothing to do with furnishing the information which called out the article in the December number of THE SIDEREAL MESSENGER, to which I understand Capt. Phythian's letter to be a reply.

Since the matter is under discussion it may not be out of place to call attention to one or two matters which I think involve the real question at issue, and which Capt. Phythian has apparently overlooked in his letter.

1. The tacit agreement originally entered into between the Naval Observatory and the Western Union Company did not contemplate that the company should have a monopoly of the government time-signals, nor that it should become a trafficker in time-signals; still less that it should use the time-service of the Naval Observatory to destroy the service for years carried on by private Observatories.

2. The furnishing of time-signals to the Western Union Company for its own use is one thing; the furnishing of these signals to that company to serve as a basis of a commercial service is quite a different matter. The Western Union Company recognizes this distinction the moment the signals come into its hands. When it furnishes the Naval Observatory time-signals to a customer he signs a contract in which it is "expressly stipulated" that he shall not "cause or suffer the signals to be transmitted to any point other than said office," meaning thereby the office of the subscriber. This prudent restriction is necessary on the part of the company in order to keep the traffic in the Observatory signals in its own hands.

Now, while the Naval Observatory may with perfect propriety furnish time-signals to the Western Union Company for its own use (and to this no one, I think, has offered objection), it is certainly questionable whether it is the proper work of that institution to become the basis of a commercial service through that company.

So far as this Observatory is concerned the preservation of the time-service is a matter of great importance. Time-signals have been sent from here for some years to a large number of roads, some of which have paid moderate amounts

for the signals, a large number paying nothing. From the revenue of the service the Observatory as it now stands has been chiefly built and furnished with instruments, and from the same source its current expenses including the pay of an assistant, are almost entirely met. For some years an earnest effort has been made in this city to build and endow a large Observatory. In a business city like St. Louis the maintainance of some public service like a time-service, is almost indispensable for success in such an effort. The time-service as maintained here has been in the largest sense a public service, and carried on with the end in view just mentioned. Within the past few months it has been displaced in some quarters by the Naval Observatory service in the hands of the Western Union Company. So far as I can see the whole service is likely to share the same fate, for even with other things equal, it is scarcely possible for a private Observatory to compete in prices with a corporation which receives its time service ready-made and free of expense.

The attitude of the Western Union Company towards scientific institutions has always been understood to be of the most friendly character. The wires of the company have frequently been used free of charge by the Observatories in longitude exchanges and other scientific work. From the labors of Henry, Morse and others, the company has received on its part a large return. Furthermore the telegraph company has had the use, so far as I know, of the time-signals of the private Observatories. This has been the case at least with the signals sent from this Observatory. In some cases the Western Union Company has transmitted our signals to subscribers, and collected money in which this Observatory has never sought to share. In fact it has been assumed that it was to the interest of the telegraph company to befriend, so far as business interests allowed, the Observatories. When, however, a superintendent of that company writes to the manager of a railroad receiving time-signals from our Observatory urging him to discontinue this service, it is somewhat difficult for the directors of Washington University to look on such action as an act of friendship to scientific institutions; and when the Superintendent of the Naval Observatory continues to furnish the telegraph company the means for displacing our service, knowing the

the use for which they are intended, it is only with considerable effort that we are able to look upon this action as "an effort to use this Observatory" (the U. S. Naval Observatory) "in forwarding the interests of other Observatories."

With regard to the whole question it may be said in brief that the interests of the private Observatories and the Western Union Telegraph Company in the matter of the public service ought to be identical—the telegraph company serving as a transmitter of time-signals originating at the Observatories. It surely ought to be possible to come to an understanding under which the rights of the Observatories as time centers and the rights of the telegraph company as time transmitters should be equally conserved. It cannot be doubted that the interests of the public lie, not in the direction of a conflict between the company and the Observatories, but in their coöperation. It will be a matter of public loss if any other solution of the matter is attempted. In either case American Astronomy will be the loser if this matter is allowed to disturb that *entente cordiale* which has always existed, and which it is so necessary should exist, between the Government Observatory on the one hand and the private Observatories on the other.

I am very truly,

H. S. PRITCHETT.

ST. LOUIS, February 18, 1890.

NOTICES FROM LICK OBSERVATORY.

PREPARED BY MEMBERS OF THE STAFF.

Return of Lexell's Comet.

The news of a remarkable and extremely important discovery in cometary astronomy, made by Mr. S. C. Chandler—so well known as a mathematician and astronomer—has just been received. Mr. Chandler has just completed a preliminary examination into certain peculiarities of the orbit of the comet discovered in July last by Mr. Brooks, and which is still under observation.

This comet has been found to revolve in an elliptical orbit about the sun in seven years. It has attracted particular

attention through the discovery, at the Lick Observatory, of the remarkable companion comets that attend it in its journey through space.

Before speaking of Mr. Chandler's discovery, it will be necessary for us to go back, in time, over one hundred years, to the date of the discovery of Lexell's comet, in 1770. Upon the computation of the orbit of this comet, Lexell found it to be revolving about the sun in a period of five and one-half years. This was considered remarkable, for the comet was visible to the naked eye, and, therefore, ought to have been seen at some of its former returns. But it had never been seen before—nor, indeed, since.

Lexell found that the aphelion of this comet was very close to Jupiter, and that it had made a very close approach to that planet in 1767. He also found that, previous to 1767, the comet had moved in an orbit whose perihelion was near Jupiter, and its distance, therefore, so great that it could not be seen from the earth. At this near approach to Jupiter in 1767, the planet's attraction on the comet was three times as great as the sun, and the comet, therefore, remained in the vicinity of Jupiter many months, its orbit becoming completely changed, so that when it finally was freed from the overpowering influence of the planet, it was thrown into a much smaller orbit, in which it would make a revolution in five and one-half years. In this small orbit it approached very near the earth, and was visible to the naked eye. At its nearest approach to the earth in 1770 it was less than one-half million miles distant. So close was the approach, indeed, that La Place computed that if the comet had any considerable mass, it would have seriously disturbed the motion of the earth in its orbit, and if the mass had been equal to that of the earth, it would have shortened the length of our year by something like three hours. From the fact that no sensible disturbance was experienced from the proximity of the comet, La Place concluded that its mass was certainly less than the one-three-thousandth part of the mass of the earth, or less than one-fortieth of the mass of our moon. It was, doubtless, vastly smaller than that.

In 1779 the comet made a still closer approach to Jupiter, and at that time the attraction on the planet was over two

hundred times as great as that of the sun, and the orbit was again changed, the perihelion becoming so great that the comet could not be seen from the earth. Burckhardt, who verified Lexell's calculations, found that before the comet came under the influence of Jupiter in 1779, its perihelion distance was probably 5.08, while that of the small orbit of 1770 was 0.67, and after the disturbance through its proximity to Jupiter, in 1779, its perihelion distance probably became 3.33, the distance of the earth from the sun being assumed unity. This body, because of its never having been seen since 1770, has been called the *lost comet*, and it has stood as the most remarkable example that we have of planetary influence in disturbing the motions of comets.

We will now return to Mr. Chandler's investigations. He found that Brooks' comet must have made a remarkably close approach to Jupiter in 1886, and that the attraction of the planet then threw the comet into its present orbit, whatever may have been its path previous to that time. This led him to suspect the identity of this comet with the famous Lexell comet of 1770, and he, therefore, attacked the problem with renewed interest. He found that, previous to the encounter with Jupiter in 1886, the Brooks' comet was moving in an entirely different orbit to that which it now moves in. The periodic time in this former orbit was twenty-seven years, and its aphelion lay outside of Saturn's orbit, and the perihelion where the present aphelion is.

Mr. Chandler, in speaking of the motion of the comet before the disturbance of 1886, says: "Several months before reaching its perihelion, it passed, near the beginning of 1886, into the sphere of Jupiter's attraction, and was deflected into a hyperbolic path about the planet, remaining for more than eight months under its control—the disturbing action of the sun during most of the interval being insignificant. The eccentricity of the hyperbola was but sligthly in excess of unity, so that the comet narrowly escaped being drawn into a closed orbit as a satellite of Jupiter. A slight diminution of the initial velocity relatively to Jupiter would have thrown it into an elliptic orbit about the planet."

Mr. Chandler also says that, at the close approach to Jupiter in 1886, the comet passed a little outside of the orbit of the third satellite, and that it is not impossible that the

unequal attraction of Jupiter and his satellite system may have caused a disruption of the cometary matter such as would produce the companions that have been discovered attending it, and that these small bodies may owe their existence to the opposing attractions of Jupiter and his satellites, in 1886.

What have been the changes that this comet has undergone since 1770 through the repeated disturbances by Jupiter it is not possible to tell at present. However, the comet is now, at least, free from the disturbing action of that planet; but this will not continue indefinitely, as it will again encounter Jupiter in 1921, under nearly the same conditions as in 1886, and its orbit will again suffer a complete change, the comet, perhaps, once more being thrown into an orbit whose perihelion distance will be so great that it will again be lost to observers, with perhaps as long a period of invisibility as it has suffered since 1770, to reappear again some time in the future, through the attractions of Jupiter, if, indeed, it can maintain its integrity as a single body under the enormous stresses to which it has been, and may again be, subjected. However this may be, there is very little doubt that Mr. Chandler has been the first to point out one of the most remarkable of all cometary histories, and that his discovery is of the first importance.

E. E. BARNARD.

MT. HAMILTON, December 5, 1889.

The Lunar Crater and Rill—Hyginus.

I have asked Mr. Barnard to make positive enlargements on glass of one of our best moon negatives. A negative of August 14, 1888 (made by Mr. Burnham), has thus been enlarged two times, and shows the Moon, therefore, exactly as it would appear in the principal focus of a telescope 1140 inches, or 95 feet, long.* I find that I can use on this positive an eye-piece of one-inch equivalent focus as a magnifier. That is, it is practicable to examine the lunar surface under perfect conditions of definition and illumination, and under a magnifying power of more than 1100 diameters, or, as if viewed by the naked eye, at a distance of 217 miles or so.

* The focus of our photographic lens is 570.2 inches

This can be done whenever one pleases, and as long as one pleases.

As a test of the excellence of definition, I may mention a discovery which I have made on Mr. Barnard's enlargement. It is well known that Mædler (and others) have mapped the walls of the *Hyginus* rill crossing the floor of the *Hyginus* crater. So far as I know, this has only been once seen. The observation is a delicate one, and could only be made when the sun is shining nearly in the direction of the preceding branch of the rill. The walls inside the crater are hardly more than 2000 *yards* apart, and their bright tops are not more than 200 to 220 *yards* wide. Yet they are plainly and obviously visible in this enlargement.

From this single example (among many others which could be given), it is possible to form a judgment of the results which a competent selenographer could draw from a series of our moon negatives. I have no hesitation in saying that a two or three years' study of such a series would produce greater results than all the previous work of observers in this line, great as these results have been. Unfortunately, the limited force at the Lick Observatory will not permit us to undertake anything more than the production of the negatives themselves. By depositing sets of these at certain scientific centers, they will be sure, sooner or later, to be studied by competent observers.—*Abstract by* E. S. HOLDEN.

Contributions of Raphael and Albrecht Durer to Astronomy.

It may not be known to all that Raphael's Madonna di Foligno has a special interest to astronomers. It is, I believe, the only painting of any note which commemorates an astronomical event. This picture was painted by Raphael in 1511, and placed in the Church of Ara-Cœli, as a votive offering from Sigismund Conti, secretary to Pope Julius II., for his miraculous escape from death by an aerolite. The picture was removed to the Convent of Foligno in 1565 by a niece of Conti's, and was carried off by the French in 1792. It was returned in 1815 and is now in the Vatican. Such is a brief sketch of the wanderings of this exquisite painting. Its purely astronomical interest consists in the portrayal of

the fall of the aerolite itself, which occupies the centre of the picture. The drawing must have been made by Raphael from the personal account of Conti (who was living in 1512), and, therefore, it has even a certain scientific value.

It does not seem to be superfluous to call attention to this item of history, which lends a slight additional interest to one of the world's great pictures. I have presented a good photograph of this painting to the Astronomical Society's library.

The contribution of Albrecht Durer to astronomy is even more pronounced and permanent, though it is unknown, I believe, to all of his biographers.

Hipparchus (B. C. 127) and Ptolemy (A. D. 136) fixed the positions of stars by celestial latitudes and longitudes, and named the stars so fixed, by describing their situation in some constellation figure. The celestial globes of that day have all disappeared, and we have only a few Arabian copies of them, not more ancient than the XIIIth century, so that we may say that the original constellation-figures are entirely lost. The situations of the principal stars in each one of the forty-eight classic constellations are verbally described by Ptolemy. In Lalande's *Bibliographie Astronomique* we find that in A. D. 1515 Albrecht Durer published two star maps, one of each hemisphere, engraved on wood; in which the stars of Ptolemy were laid down by Heinfogel, a mathematician of Nuremberg. The stars themselves were connected by constellation-figures, drawn by Durer. These constellation-figures of Durer, with but few changes, have been copied by Bayer in his *Uranometria* (A. D. 1603); by Flamsteed in *Atlas Cœlestis* (1729); by Argelander in *Uranometria Nova* (1843), and by Heis in *Atlas Cœlestis Novus* (1872), and have thus become classic. It is a matter of congratulation that designs which are destined to be so permanent should have come down to us from the hands of so consummate a master. E. S. H.

Photographic Photometry.

Nature for October 10, 1889 (p. 584), has an abstract of a very important paper by Capt. Abney, F. R. S., on this subject, as follows:

"The author concludes, from his experiments, that the deposit of silver made by different intensities of light varies [in density] directly as the intensity of light acting—this, of course, within such limits that the reversal of the image is not commenced and that the film is not at any part exhausted of the silver salt which can be reduced."

Experiments by Mr. Leuschner on this same question are to be published. E. S. H.

The Chief Discoverers of Comets.

Mr. W. F. Denning, in the *Observatory* for November, 1889, gives the following table, which is well worth reprinting. It has been completed to 1890.

Name of Discoverer.	Period of Observations.	No. of Comets discovered.
Charles Messier	1760-1798	13
P. F. A. Mechain	1781-1799	8
Carolina Herschel	1786-1795	6
Jean Louis Pons	1802-1827	30
Padre di Vico	1844-1846	5
T. J. C. A. Brorsen	1846-1851	5
Wilhelm Klinkerfues	1853-1863	6
Carl Bruhns	1853-1864	7
Giovan B. Donati	1855-1864	5
F. Aug. T. Winnecke	1858-1881	13
Wilhelm E. Tempel	1859-1884	18
Lewis Swift	1862-1890	8
J. Coggia	1867-1877	7
Alphonse Borrelly	1871-1890	7
E. E. Barnard	1881-1890	13
W. R. Brooks	1883-1890	12

Mr. Brett on the Physical Condition of Mars.

Publications No. 5 of the Society (page 122), contains a résumé of a recent paper by M. Flammarion, on the physical condition of Mars. The fundamental asumption of that paper is that the dark markings on Mars represent areas of water. This assumption, while probable, is not yet proved.

A paper by Mr. John Brett, F. R. A. S., in the *Monthly Notices Royal Astronomical Society* for 1877 (vol. 38, p. 58), on the same subject, has not, it appears, received the attention it deserves.

It is worth while to summarize it here, in order to accent the wide difference of views held by observers of this planet, and because of its suggestiveness in many regards.

Mr. Brett's conclusions are based on his observations of

1877. He points out, first, that Mars does not show the same delicacy of detail (as Jupiter, for example), under like conditions; and he attributes to Mars an atmosphere of considerable opacity on this account. As the details of the planet's surface vanish before they reach the limb, while they are best seen at the center of the disc, and as the disc is brightest at the limb, the conclusion is that the markings themselves are situated below the surface of a tolerably dense atmosphere. The chief topographical features on Mars are permanent, and hence the body of the planet is solid. There are few or no clouds on Mars. This fact alone is fatal to the belief that the "land" and "water" on Mars act as on the earth. A whole opposition of Mars may pass and no changes of its own atmosphere be made out.

It is certain [illegible]m spectroscopic observations) that watery vapor exists in the atmosphere of Mars. It does not necessarily follow that the vapor is anywhere condensed into visible clouds. If the polar caps are veritable "snow-caps," then clouds *must* exist in the atmosphere. Chilled water-vapor *must* produce clouds. As no (or few) evidences of clouds exist on the euqatorial regions of the planet, Mr. Brett's conclusion is that the so-called "snow-caps" cannot be snow-fields at all.

All the *dark* markings disappear before they reach the limb of the planet, while the "snow-caps" themselves are best seen at the limb, and often project far beyond it. This projection has been laid to irradiation. Mr. Brett thinks that the "snow-caps" are, in fact, clouds in the higher and colder regions of the atmosphere. The dark patches near the caps he supposes to be their shadows. He assumes that the regions near the poles are the only ones cool enough to condense the (invisible) water-vapor into visible clouds. Moreover, it follows that the surface of the planet in general is hot—hot enough to make the formation of clouds impossible; and it is likely, also, that the "seas" are not water.

Mr. Brett also points out that ordinary atmospheric absorption will not account for the fact that the central parts of Mars are red, while the limbs are "white" (lemon-yellow or yellowish white in the great telescope.) The nature of the absorption at the limb is one of the most difficult points to account for on a theory like that of M. Flammarion's,

previously cited. Mr. Brett attempts no special explanation of the differences of color between the "seas" and the "continents,"—nor does he mention the "canals," of course.

The above summary is given, as was said, simply to indicate the wide differences between plausible explanations of the phenomena observed on Mars. The fact that such differences of opinion are even possible indicates the unsatisfactory nature of our knowledge of this planet. E. S. H.

A SIMPLE BREAK-CIRCUIT FOR CLOCKS.

WILLARD P. GERRISH.

For THE MESSENGER.

A break-circuit arrangement has been recently constructed and put into operation at Harvard College Observatory which works very satisfactorily. A small permanent horseshoe magnet was rigidly attached to the pendulum rod of a clock. A light brass contact spring, having at its free end a small soft iron armature, was fixed in front of the pendulum in such a position that the magnet would pass directly over it at the middle of each vibration. The contact spring was fitted with screws to regulate the amount of its motion. It was adjusted to rest with a slight pressure on a platinum tip at the end of one of these screws through which the circuit was completed. At each beat of the pendulum the spring is lifted by a slight amount, breaking the circuit, which is immediately closed again after the pendulum and magnet have passed. As the magnet never comes into contact with the armature, friction is entirely avoided, the only work done being that required to lift the spring. Since the spring is very light a minimum amount of energy is absorbed in its operation. This form of break-circuit is easily constructed and can be applied in a few minutes to any clock. It will make or break the circuit with equal facility, as the contact spring strikes a fixed stop in rising as well as in falling, and in so doing in no way affects the pendulum. Although the device may have been tried before, it is not in general use and is worthy of the attention of astronomers on account of its cheapness and simplicity. It has been in

use during the past two months for giving the signals which control the motion of the Draper eight-inch photographic telescope.

February 12, 1890.

COMET 1889 V (BROOKS, JULY 6).

DR. H. C. WILSON.

For THE MESSENGER.

This comet promises to be one of the most interesting ones yet discovered, not because of its brilliancy, but because of its probable identity with the lost Lexell comet of 1770 and of the interesting and exceedingly difficult problem which it offers in the calculations of its perturbations and the tracing of its path during the period of 119 years during which it has been lost to sight. The comet is at present moving in a short ellipse having a period of a little over seven years, but in an article published in the *Astronomical Journal*, No. 204, Mr. S. C. Chandler pointed out the fact that in 1886 the comet must have passed very close to the planet Jupiter, in fact through the system of his satellites, and its orbit must then have been radically changed. In a later paper (*Astr. Jour.* No. 205), Mr. Chandler gives the results of a rough calculation of the principal perturbations by Jupiter, that is, from Jan. 24 to Sept. 14, 1886, and attempts to trace the course of the comet backward from that time, reaching some very remarkable conclusions. He finds that the encounter with Jupiter in 1886 effected a complete transformation of the comet's orbit. Instead of the present small seven years' ellipse, it was previously moving in a large one of twenty-seven years' period, whose aphelion lay outside of Saturn's orbit, and whose perihelion was almost exactly at the present aphelion distance. The directions of the lines of the apsides and nodes were reversed and turned through an angle of about twenty degrees. The plane of the orbit was also tilted about fourteen degrees.

A comparison of the following sets of elements will show the radical character of the changes:

	Before 1886.		After 1886.	
$T =$	1886 Nov. 28.779 Gr. M. T.		1889 Sept. 30.0119 Gr. M. T.	
$\pi =$	203° 03′.7	1890.0	1° 26′ 17″.3	1890.0
$\Omega =$	179 13 .4		17 58 45 .3	
$i =$	7 43 .8		6 04 10 .5	
$e =$	0.3947		0.470704	
$a =$	8.9896		3.684682	
$q =$	5.4411		1.950229	
Period $=$	26.95 years.		7.0730 years.	

Several months before reaching perihelion the comet passed, near the beginning of 1886, into the sphere of Jupiter's attraction, and was deflected into a hyperbolic path about that planet, remaining for more than eight months under its control; the disturbing influence of the sun during most of the interval being insignificant. The eccentricity of the hyperbola was but little over unity, the comet having narrowly escaped being drawn permanently into Jupiter's satellite system. At the point of nearest approach to Jupiter May 20, 1886, the comet was distant only nine diameter's of the planet from his center, almost as near as the third satellite. It is not impossible that the comet may have come into such a position with reference to the satellites and planet, that their unequal attraction upon different parts of its diffuse mass may have tended to disruption, and have brought about the separation of portions such as were actually observed during its present apparition.

Professor Bredichin has added almost certainty to this surmise of Mr. Chandler's by publishing, in *Astronomische Nachrichten* No. 2949, the results of some calculations which he has made upon the orbits of the companion comets, which were detected by Mr. Barnard in the early part of August, 1889, and were observed until about the end of October. Taking Mr. Chandler's first set of elliptic elements (*Astr. Jour.* No. 204) for the orbit of the principal mass of the comet, designated *A*, Professor Bredichin has computed, by a differential method, the orbits of the masses *C* and *E*, and finds that they intersect the orbit of *A* at almost the same point, and that point is about 1° beyond the present aphelion point, almost exactly where the comet was nearest to Jupiter. The orbit of the mass *B* is between the orbits of *A* and *C*, and that of *D* between those of *C* and *E*.

Tracing backward the course of the comet, with the elements of the 27 year orbit, Mr. Chandler found that the

comet would not have approached near enough to any planet to have its path greatly changed until 1779. In that year, however, the comet must have come so near to Jupiter as to pass under its control and experience a radical change of its orbit at the point of longitude where Lexell's comet underwent its notable disturbance in that year. This coincidence, in time and place, of approach to Jupiter is very strong presumptive evidence of the identity of the two comets. It is certainly very striking if it be merely an accidental coincidence. Moreover, there is a strong resemblance between some of the elements of Comet 1889 V, before 1886, and those of Lexell's comet after 1779, as shown in the following table, in which Mr. Chandler's elements are carried back to 1770.

	Lexell's Comet after 1779.			Comet 1889 V before 1886.
	Burckhardt.	Le Verrier.		Chandler.
		$\mu=-0.10$	$\mu=+0.35$	
π	301° 19′	110° 00′	258° 40′	201°24′
☊	183 15	178 06	175 27	177 34
i	14 42	18 50	11 27	7 43
e	0.478	0.535	0.533	0.395
a	6.388	9.000	9.000	8.990

The two sets of elements by Le Verrier were selected from a large number of possible sets obtained by varying the indeterminate quantity μ. These both correspond to a period of about twenty-seven years. Le Verrier found that the observations of 1770 could be represented equally well by a number of orbits, differing slightly, it is true, but enough to make an enormous difference when the perturbations by Jupiter in 1779 were to be calculated. He therefore gave up the attempt to calculate definitive elements of the comet's new orbit, but introduced into the expression for each an indeterminate quantity μ, by the variation of which elements could be obtained to suit different conditions. He has given a table of such elements, corresponding to different values of , in which it may be seen that the values of ☊ and i vary slightly within very narrow limits while the other elements have a very wide range of variation. The agreement of the ☊ of the comet of 1889 with that of Lexell's is very striking and the inclination also agrees within reasonable limits. The semi-major axis a also agrees with the two selected from Le Verrier's table, but these depend upon the assumption of the 27 year period. The fact that four periods of 26.95

years are very nearly equal to the interval 107 years between the approaches of the two comets to Jupiter in 1779 and 1886 would seem to attest the substantial correctness of the period.

There is, however, room to doubt, as Mr. Chandler himself admits, whether the method which he pursued is adequate to the attainment of such precision in the dimensions of the ellipse previous to 1886, as the above implies. It is quite possible that the period derived that way may be in error by several years and even that the comet may have made only three revolutions in the 107 years. In this case Mr. Chandler points out the fact that the comet would have approached Jupiter again in 1815 and 1850, suffering enormous perturbations, the effect of which it would be impossible to calculate. The probability that this may have been the case is heightened by the fact that the very elements of Lexell's comet which Mr. Chandler selects give periods of 33 years and slightly different ones would give 35 and 36 years.

In the *Bulletin Astronomique*, tome VI, Nov. 1889, Mr. Schulhof has discussed the possibility of identity of several pairs of periodic comets by means of a criterion which has been expressed in a neat mathematical formula by M. Tisserand. This criterion depends upon the fact that a body revolving about another as a center has the same velocity for equal radius vectors. A comet under the influence of strong perturbations by a planet revolves for the time about the planet as a center, and, therefore, has equal velocities at the two points of entering and leaving the sphere of influence of the planet, the one point being in the old, the other in the new orbit. M. Tisserand expresses this relation very approximately by the formula,

$$\frac{1}{a_1} - \frac{1}{a_2} = \frac{2\sqrt{A}}{R^2}(\sqrt{p_2}\cos i_2 - \sqrt{p_1}\cos i_1),$$

in which a_1, a_2, p_1, p_2, i_1, i_2 are the semi-major axes, parameter and inclinations of the old and new orbits of the comet, and A and R are the semi-major axis and radius vector of the planet's orbit at the point of nearest approach. This formula may be separated in two equal parts of the form

$$n = \frac{1}{a} + \frac{2\sqrt{A}}{R^2}\sqrt{p}\cos i,$$

which are convenient in comparing comets which exhibit signs of identity. In the following table the values of n as computed by Mr. Schulhof are given together with the elements of the 21 known periodic comets, and their longitudes at the point of proximity to Jupiter:

Name.	n	π	Ω	i	e	a	l
1. Denning 1881	0.412	19°	66°	7°	0.83	4.28	223°
2. Piggott 1783	0.473	50	56	45	0.55	3.26	233
3. Brorsen 1846	0.476	116	103	31	0.79	3.14	283
4. Finlay 1886	0.843	8	52	3	0.72	3.54	205
5. Lexell 1770	0.485	356	132	2	0.79	3.16	184
6. Biela 1772	0.486	110	257	17	0.72	3.58	268
7. Helfenzrieder 1766	0.493	251	74	8	0.86	2.93	80
8. Wolf 1884	0.496	19	206	25	0.56	3.58	210
9. D'Arrest 1851	0.503	323	148	14	0.66	3.44	153
10. Faye 1843	0.507	50	209	11	0.56	3.81	209
11. Winnecke 1858	0.508	276	114	11	0.75	3.14	113
12. Tuttle 1858	0.527	201	175	20	0.67	3.52	0
13. Brooks 1889	0.530	2	18	6	0.47	3.67	185
14. Tempel-Swift 1869	0.534	43	297	5	0.66	3.11	223
15. De Vico 1844	0.537	343	64	3	0.62	3.10	162
16. Brooks 1886	0.553	230	52	13	0.61	3.41	53
17. Tempel 1873	0.562	306	121	13	0.55	3.00	125
18. Blanpain 1819	0.566	67	77	9	0.69	2.85	247
19. Barnard 1884	0.566	306	5	5	0.57	3.08	126
20. Tempel 1867	0.590	236	101	6	0.51	3.19	60
21. Encke 1795	0.591	157	335	14	0.85	2.21	335

It will be seen from this table that the quantity n does not vary very widely for all the twenty-one comets. For a single comet the perturbations by a single planet can produce only a slight variation. Schulhof puts the limit of this variation at 0.01. This criterion then would seem to exclude the possibility of the identity of the two comets now under consideration, for the difference between the values of n is 0.045.

But there is an exceptional case in which n is not constant, that is, when the comet's path is disturbed by a second planet, and it seems probable that this may have been the case with Lexell's comet. In a later paper (*Bull. Astr.* Dec. 1889) Mr. Schulhof, after seeing Mr. Chandler's results, shows that the comet may have approached near to Saturn between 1779 and 1886, so that his action has modified the value of n, calculated on the hypothesis that Jupiter was the only disturbing body. This indispensable condition of a strong perturbation by Saturn gives a means of determining ap-

proximately the period of revolution which the comet must have had, on the supposition of identity, after 1779 and before 1886. An examination of Le Verrier's table of elements showed that the comet after leaving Jupiter in 1779 would approach quite near to Saturn if the value of μ were -0.08 or $+0.32$. The two corresponding sets of elements are given below with those obtained by Mr. Chandler:

μ	T	π	Ω	i	e	a	P
-0.08	1812.35	120.5°	178.1°	18.7°	0.576	10.55	34.27y
$+0.32$	1781.06	250.0	175.7	11.9	0.615	10.70	35.00
	1886.91	203.1	179.2	7.7	0.395	8.99	26.95

On the first supposition the comet was at its shortest distance from Saturn's orbit in heliocentric longitude 6° about 1808.0, 1842.2 and 1876.5; and on the second supposition in longitude 8° about 1785.3, 1820.3 and 1855.3; Saturn being at the same points about 1790.9, 1820.4, 1849.9 and 1879.4. The close coincidence of the dates 1820.3 and 1820.4 points to the second set of elements as the more probable, but this would make the period almost uniform from 1779 to 1886, while in order to reconcile the values of n the period is required to be greater before 1886. Mr. Schulhof finds the criterion to be best satisfied by supposing the period to have been about 32 years from 1779 to 1849, at which epoch the comet passed near Saturn and its period was increased to about 42 years. This would avoid bringing the comet near to Jupiter in 1815 and 1850 or at any time between 1779 and 1886.

For the next four periods of about seven years the comet will be free from serious perturbations, appearing in 1896, 1903, 1910 and 1917 under favorable conditions for observation, but in 1921 it will again enter into the sphere of Jupiter's activity and undergo another violent transmutation.

Altogether the investigations of Messrs. Chandler, Schulhof and Bredichin are exceedingly interesting although the results are as yet very uncertain. The problem is one that will tax to the utmost the powers of mathematical research, and is of the greatest importance in its bearing upon our knowledge of the constitution and origin of these erratic members of the solar system. What a grand achievement if the computer shall succeed in following, with reasonable certainty, the wanderings of this wisp of nebulosity, as it is whisked about from one ellipse to another by the giant planets Jupiter and Saturn!

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury will be at superior conjunction on the morning of April 9. During the first days of March it may be visible to the naked eye a little before sunrise. The best observations of this planet, however, have been made when the sun was above the horizon and the planet at as great an altitude as possible. It was by following the planet through the day, even when it was more distant than the sun, that Professor Schiaparelli made his brilliant discovery of the rotation period of Mercury, which we referred to last month. It is only when the phase of Mercury is nearly full, and therefore when the planet is on the farther side of its orbit, its disk being then only 5″ in diameter, that the general configuration of its surface markings can be seen.

If it be true that the rotation period of Mercury is the same as that of its revolution around the sun, and this does not seem to be at all unreasonable, what strange conditions of affairs must exist upon that planet! One hemisphere in perpetual day, the other in everlasting night! One in perpetual heat, the other in intense and never ceasing cold! At one point upon the sunward hemisphere the sun is in the zenith, oscillating 23° 41′ alternately to the east and west, at others alternately above and below the same point of the horizon, during the period of 88 of our days. Many interesting, although of course useless, questions present themselves to one's mind in contemplating these conditions. Are there living intelligent beings there? On what part of the globe do they live? How do they measure time? etc.

Venus has just passed superior conjunction, becoming now "evening star." In the latter part of March it will be visible to the eye in the west after sunset but so low that telescopic observations will be unsatisfactory. The success, however, of Professor Schiaparelli in seeing the markings on Mercury in full sunlight should encourage observers to study Venus in the same way. Its position this month will be very favorable for study of Venus in that way, as the phase is almost full and the declination will permit the planet to reach an altitude of from 45° to 50°.

Mars will be in Scorpio, during this month, just a little north of the red star Antares. The two ruddy objects, visible in the morning in the south, will be nearly alike in brightness and color.

Jupiter is in the constellation of Capricorn, and may be found in the southeast in the morning, it being brighter than any of the stars in that part of the sky.

Saturn may be easily found in the evening. Looking toward the east at eight o'clock one sees, about half way to the zenith, two bright stars and a group of fainter ones in the form of a sickle. The brighter of the two stars is Saturn, whose yellow light also distinguishes him from the other, Regulus, whose light is bluish white. We have had several good views of Saturn lately with the eight-inch refractor. The white equatorial belt is conspicuous. The divisions between the rings are becoming difficult to see with small telescopes, because the rings are turned so nearly edgewise to us.

Uranus will be at opposition to the sun April 14, and so can be well seen in the evening.

Neptune is still visible in the evening, between the Hyades and Pleiades. Our class in practical astronomy on one evening recently looked up this planet and found two objects in the field of view, of almost exactly the same brightness and color. The only way to distinguish between the planet and star, as the definition was somewhat poor, was by the difference in intensity of the light of the two objects, the light of Neptune being duller than that of the star.

1890.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
			MERCURY.		
Mar. 26	23 37.5	− 4 48	5 37 A.M.	11 21.1 A.M.	5 07 P.M.
April 5	0 46.4	+ 3 33	5 33 "	11 50.5 "	6 08 "
15	2 02.5	+12 47	5 32 "	12 27.1 P.M.	7 22 "
			VENUS.		
Mar. 26	0 57.2	+ 4 56	6 18 A.M.	12 40.5 P.M.	7 03 P.M.
April 5	1 43.1	+ 9 51	6 04 "	12 47.1 "	7 30 "
15	2 30.2	+14 23	5 53 "	12 54.6 "	7 56 "
			MARS.		
Mar. 26	16 30.8	−21 03	11 36 P.M.	4 11.7 A.M.	8 47 A.M.
April 5	16 40.5	−21 37	11 09 "	3 41.9 "	8 14 "
15	16 46.1	−22 06	10 38 "	3 08.2 "	7 38 "
			JUPITER.		
Mar. 26	20 34.1	−19 07	3 34 A.M.	8 18.3 A.M.	1 03 P.M.
April 5	20 40.7	−18 44	3 00 "	7 45.8 "	12 32 "
15	20 46.5	−18 24	2 25 "	7 12.0 "	11 59 A.M.
			SATURN.		
Mar. 26	10 02.9	+13 49	2 45 P.M.	9 44.7 P.M.	4 44 A.M.
April 5	10 01.1	+13 58	2 04 "	9 03.7 "	4 04 "
15	9 59.8	+14 04	1 22 "	8 23.1 "	3 24 "
			URANUS.		
Mar. 26	13 35.3	− 9 17	7 50 P.M.	1 16.5 A.M.	6 43 A.M.
April 5	13 33.7	− 9 08	7 09 "	12 35.7 "	6 03 "
15	13 32.1	− 8 58	6 27 "	11 54.7 P.M.	5 22 "
			NEPTUNE.		
Mar. 26	4 02.2	+19 03	8 22 A.M.	3 45.1 P.M.	11 08 P.M.
April 5	4 03.2	+19 07	7 43 "	3 06.8 "	10 30 "
15	4 04.5	+19 11	7 65 "	2 28.7 "	9 52 "
			THE SUN.		
Mar. 26	0 22.2	+ 2 24	5 52 A.M.	12 05.7 P.M.	6 20 P.M.
April 5	0 58.6	+ 6 16	5 33 "	12 02.6 "	6 32 "
15	1 35.3	+ 9 56	5 16 "	11 59.9 A.M.	6 44 "
			THE MOON.		
Mar. 21	1 01.1	+ 0 46	6 50 P.M.	12 59.0 P.M.	7 17 P.M.
26	5 18.6	+22 29	9 13 A.M.	5 01.3 "	12 56 A.M.
31	9 42.9	+18 05	1 28 P.M.	9 05.2 "	4 32 "
April 5	13 47.8	− 6 30	6 55 "	12 49.7 A.M.	6 34 "
10	17 34.1	−23 09	11 45 "	4 19.8 "	8 52 "
15	22 44.4	−13 12	3 57 A.M.	9 09.6 "	2 32 P.M.

[The above tables give local times for the Central Meridian and latitu +44° 28′.]

Ephemerides of Saturn's Satellites.

[Computed by A. Marth, Monthly Notices R. A. S., vol. L, No. 1, p. 56.]

Mar. 15	12.5 p. m.	En. s.
	3.7 p. m.	Mi. n.
	6.6 p. m.	Te. n.
	8.2 p. m.	Di. s.
16	1.5 a. m.	Rh. s.
	7.8 a. m.	Tit. s. 37″
	2.3 p. m.	Mi. n.
	5.3 p. m.	Te. s.
	9.4 p. m.	En. s.
17	4.6 a. m.	Rh. e.
	5.0 a. m.	Di. n.
	12.9 p. m.	Mi. n.
	1.9 p. m.	En. n.
	3.9 p. m.	Te. n.
18	7.7 a. m.	Rh. n.
	1.9 p. m.	Di. s.
	2.5 p. m.	Te. s.
	10.7 p. m.	En. n.
	10.8 p. m.	Mi. s.
19	10.8 a. m.	Rh. w.
	1.2 p. m.	Te. n.
	3.2 p. m.	En. s.
	9.5 p. m.	Mi. s.
	10.7 p. m.	Di. n.
20	11.8 a. m.	Te. s.
	1.9 p. m.	Rh. s.
	8.1 p. m.	Mi. s.
21	12.1 a. m.	En. s.
	7.5 a. m.	Di. s.
	10.5 a. m.	Te. n.
	4.5 p. m.	En. n.
	5.0 p. m.	Rh. e.
	6.7 p. m.	Mi. s.
22	9.1 a. m.	Te. s.
	4.4 p. m.	Di. n.
	5.3 p. m.	Mi. s.
	8.1 p. m.	Rh. n.
23	7.8 a. m.	Te. n.
	3.9 p. m.	Mi. s.
	5.8 p. m.	En. s.
	11.1 p. m.	Rh. w.
24	12.9 a m.	Tit .n. 37″
	1.2 a. m.	Di. s.
	6.4 a. m.	Te. s.
	2.5 p. m.	Mi. s.
25	2.2 a. m.	Rh. s.
	5.1 a. m.	Te. n.
	10.0 a. m.	Di. n.
	1.2 p. m.	Mi. s.
	7.1 p. m.	En. n.
26	3.7 a. m.	Te. s.
	5.3 a. m.	Rh. e.
	11.6 a. m.	En. s.
Mar. 26	11.8 a. m.	Mi. s.
	6.9 p. m.	Di. s.
27	2.4 a. m.	Te. n.
	8.4 a. m.	Rh. n.
	8.5 p. m.	En. s.
	9.7 p. m.	Mi. n.
28	1.0 a. m.	Te. s.
	3.7 a. m.	Di. n.
	11.5 a. m.	Rh. w.
	12.9 p. m.	En. n.
	8.3 p. m.	Mi. n.
	11.7 p. m.	Te. n.
29	12.5 p. m.	Di. s.
	2.6 p. m.	Rh. s.
	6.9 p. m.	Mi. n.
	9.8 p. m.	En n.
	10.3 p. m.	Te. s.
30	2.2 p. m.	En. s.
	5.5 p. m.	Mi. n.
	5.7 p. m.	Rh. e.
	9.0 p. m.	Te. n.
	9.4 p. m.	Di. n.
31	4.2 p. m.	Mi. n.
	7.6 p. m.	Te. s.
	8.8 p. m.	Rh. n.
April 1	5.6 a. m.	Tit. s. 38″
	6.6 a. m.	Di. s.
	6.3 p. m.	Te. n.
	11.9 p. m.	Rh. w.
2	3.0 p. m.	Di. n.
	4.9 p. m.	Te. s.
3	3.0 a. m.	Rh. s.
	3.6 p. m.	Te. n.
	11.9 p. m.	Di. s.
4	6.1 a. m.	Rh. e.
	2.2 p. m.	Te. s.
5	8.7 a. m.	Di. n.
	9.2 a. m.	Rh. n.
	12.9 p. m.	Te. n.
	6.2 p. m.	En. n.
	8.6 p. m.	Mi. s.
6	11.5 a. m.	Te. s.
	12.3 p. m.	Rh. w.
	5.5 p. m.	Di. s.
	7.2 p. m.	Mi. s.
7	10.2 a m.	Te. n.
	3.3 p. m.	Rh. s.
	5.8 p. m.	Mi. s.
	7.5 p. m.	En. s.
8	2.4 a. m.	Di. n.
	8.8 a. m	Te. s.
	12.0 m.	En. n.
April 8	1.9 p. m.	Di. c. Jap. 3″
	4.4 p. m.	Mi. s.
	6.4 p. m.	Rh. e.
	10.9 p. m.	Tit. n. 37″
9	6.7 a. m.	Mi. c. prec. end of ring 4″
	6.9 a. m.	Mi. c. Jap. 0″
	7.5 a. m.	Te. n.
	7.7 a. m.	Jap. c. prec. end of ring 4″ n.
	10.7 a. m.	Jap. occulted by ring. Disapp. 3″ n.
	11.2 a. m.	Di. s.
	3.0 p. m.	Mi. s.
	8.9 p. m.	En. n.
	9.5 p. m.	Rh. n.
10	12.8 a. m.	Jap? emerging from behind the ball in the space within the crape ring.
	5.5 a. m.	Jap. reapp. from occultation by the ring 2″ s.
	6.1 a. m.	Te. s.
	7.5 a. m.	Jap. c. foll. end of ring 3″ s.
	10.6 a. m.	Te. c. Jap. 4″.
	1.3 p. m.	En. s.
	1.6 p. m.	Mi. s.
	8.1 p. m.	Di n.
11	12.6 a. m.	Rh. w.
	4.8 a. m.	Te. n.
	12.3 p. m.	Mi. s.
	10.2 p. m.	En. s.
12	3.4 a. m.	Te. s.
	3.7 a. m.	Rh. s.
	4.9 a. m.	Di. s.
	2.6 p. m.	En. n.
	10.2 p. m.	Mi. n.
13	2.1 a. m.	Te. n.
	6.8 a. m.	Rh. e.
	1.7 p. m.	Di. n.
	8.8 p. m.	Mi. n.
	11.5 p. m.	En. n.
14	12.7 a. m.	Te. s.
	9.9 a. m.	Rh. n.
	3.9 p. m.	En. s.
	7.4 p. m.	Mi n.
	10.6 p. m.	Di. s.
	11.4 p. m.	Te. n.

En. = Enceladus; Di. = Dione; Jap. = Japetus; Mi. = Mimas; Rh. = Rhea; Te = Tethys; Tit. = Titan; c. = conjunction; e. = eastern elongation; w. = western elongation; n. = north of center of planet; s. = south of center of planet. The conjunctions of the three innermost planets with the ends of the ring take place in the case of Mimas about 3.0h, Enceladus, 3.2h, Tethys, 3.5h before and after the predicted conjunctions with the center, which are not observable.

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m
Mar. 29	μ' Cancri	6½	8 05	90	9 32	301	1 26
Apr. 5	88 Virginis	6½	9 30	103	10 40	324	1 09
5	B.A.C. 4647	6½	14 38	125	15 51	301	1 13
7	ζ^3 Librae	6	9 05	123	10 02	289	0 58
7	ζ^4 Librae	5½	10 12	119	11 15	295	1 03
13	κ Capricorni	5	15 16	45	16 11	291	0 55

Minima of Variable Stars of the Algol Type.

	R. A. h m s	Decl. ° ′	Range of Magnitude.	Period. d h m	Approx. Central Times of Minima.
U Cephei.........	0 52 32	+81 17	7.1 to 9.2	2 11 50	Mar. 20, 11h P.M.; 25, 11h P.M.; 30, 11h P.M.; April 4, 10h P.M.; 9, 10h P.M.; 14, 10h P.M.
Algol...............	3 01 01	+40 32	2.3 to 3.5	2 20 49	Mar. 19, 5h A.M.; 22, 2h A.M.; 24, 11h P.M.; 26, 8h P.M.
λ Tauri...........	3 54 35	+12 11	3.4 to 4.2	3 22 52	Mar. 19, 7h P.M.; 23, 6h P.M..
R Canis Maj...	7 14 30	−16 11	5.9 to 6.7	1 03 16	Mar. 23, 9h P.M.; 31, 8h P.M.; April 1, 11h P.M.; 9, 10h P.M.
S Cancri..........	8 37 39	+19 26	8.2 to 9.8	9 11 38	Mar. 25, 10h P.M.; April 13, 9h P.M.
δ Libræ...........	14 55 06	− 8 05	5.2 to 6.2	2 07 51	Mar. 16, 10h P.M.; 23, 10h P.M.; 30, 10h P.M.; Apr. 6, 9h P.M.; 13, 9h P.M.
U Coronæ.......	15 13 43	+32 03	7.5 to 8.9	3 10 51	Mar. 22, 1h A.M.; 28, 11h P.M.
U Ophiuchi......	17 10 56	+ 1 20	6.0 to 6.7	0 20 08	Mar. 23, 1h A.M.; 28, 2h A.M.; April 2, 3h A.M.; 7, 4h A.M.; 12, 5h A.M.

Phases of the Moon.

			Central Time. d	h m	
New Moon................................	1890	March	20	3 01	P. M.
First Quarter..............................	"	"	28	3 33	A. M.
Full Moon..................................	"	April	5	3 24	A. M.
Last Quarter..............................	"	"	12	4 53	A. M.
Perigee......................................	"	March	17	8 54	P. M.
Apogee......................................	"	"	29	3 42	P. M.
Perigee......................................	"	April	13	11 12	A. M.

COMET NOTES.

Transit of Comet d, 1889, (Brooks, July 6,) over a star. On the evening of January 17, Mr. O. C. Wendell made his customary examination of the physical peculiarities of this comet previous to taking transits. This was done not only from the fact that this body has sent off several companion comets already, but also because on the two nights previous, a suspicion had been entertained of a subdivision in the nucleus. This latter appearance was probably due to bad seeing, as was thought possible at the time. On the night in question, under a careful scrutiny, no apparent subdivision was seen at the first, but, on the other hand, it was remarked that the comet's nucleus was unusually sharp and well defined. Transits were accordingly taken, but before finishing them there be-

gan to be the appearance of two nuclei, one sharp and stellar, the other having the more usual cometary appearance. Then it at once became evident that the comet had passed centrally over a star, which had accordingly been taken in transit. As the comet moved away, it was estimated that the increase in the star's brightness was possibly two-tenths of a magnitude. In other words, the comet had passed centrally over a 10.7 magnitude star with scarcely any diminution of its light.

Comet 1886 VII (*Finlay*). Mr. L. Schulhof at Paris is about to compute definitive elements of this comet and desires all unpublished observations to be communicated as soon as possible.

Comet 1889 I (*Barnard, Sept. 2, 1888*). This comet was observed from Sept. 4, 1888, to Feb. 17, 1889, and from May 22 to Oct. 22, 1889, and perhaps later observations have not been published. Dr. A. Berberich (*Astr. Nach.* No. 2946) has computed very accurate elements of its orbit from all the published observations. Fifteen normal places were formed, which are all represented within their possible errors by the new elements.

$$T = 1889 \text{ Jan. } 31.209083 \text{ Berlin mean time.}$$
$$\left.\begin{array}{l}\omega = 340^\circ\ 27'\ 39.74'' \\ \Omega = 357\ \ 25\ \ 14.93 \\ i = 116\ \ 22\ \ 12.83\end{array}\right\} 1889.0$$
$$\log q = 0.2588515 \qquad q = 1.814894$$
$$e = 1.0010863$$

It will be seen from the value of e that the orbit of this comet is an hyperbola. Dr. Berberich thinks he has found the cause of deviation from a parabolic path in a near approach of the comet to the orbit of Uranus in 1882. The angular distance between the comet and planet as seen from the sun was 10° and the actual distance between them about three times the earth's distance from the sun. The perturbation then produced by the planet upon the comet's motion was in the right direction and, considering the long duration of its influence, was probably sufficient to change the orbit from a parabola to its present form. The comet is now moving almost directly toward Jupiter, its distance at the beginning of this year being about the same as the earth's distance from the sun, so that further perturbations are likely again to change the form of the orbit. It is possible that the comet will still be visible for a few months with the aid of large telescopes, the theoretical brightness being about 0.09 of that at the time of discovery Sept. 2, 1888. The following ephemeris by Dr. Berberich will enable observers to find the place of the comet and test the powers of their telescopes and eye-sight in this direction. The only chance to see it will be about two hours before sunrise.

1890 Berlin midnight	α app. h m s	δ app. ° ′	log r	log Δ
March 8	18 55 00	−10 06.7	0.6832	0.7122
12	54 43	− 9 56.1		
16	54 14	− 9 45.4	0.6895	0.7066
20	53 33	− 9 34.7		
24	52 38	− 9 23.9	0.6956	0.7004
28	51 29	− 9 13.1		
April 1	50 05	− 9 02.4	0.7016	0.6938
5	48 28	− 8 51.7		
9	46 36	− 8 41.2	0.7076	0.6871
13	44 28	− 8 30.9		

Sunspots during the past month have been very few and small. The following is the record of observations at Carleton College Observatory from Dec. 18, 1889, to Feb. 20, 1890. The instrument employed is the 8-inch refractor, full aperture, the image of the sun being projected through a comet eye-piece upon a screen. The diameter of the image is usually about 15 inches and the spots which are distinctly seen are counted. These observations are made by Miss C. R. Willard and H. C. Wilson.

Date (Civil) 1889.	Central Time.	No. groups	No. spots...	Faculæ......	Observer....	Remarks.
Dec. 18	12^h00^m	1	4	0	H.C.W.	
20	12 20	2	15	10	"	Both groups in north latitude.
25	9 45	1	10	0	"	One large spot followed by small ones in S. latitude.
26	12 30	1	18	1	"	
27	2 30	2	25	12	"	New large spot surrounded by brilliant faculæ near east limb. Fine aurora last night from 9^h to 3^h.
30	12 30	2	4	15	"	Group near west limb surrounded by brilliant facula. Spot to east of center has two umbræ.
1890.						
Jan. 2	12 00	1	1	0	"	
7	3 15	4	12	6 gr.	"	Two groups of spots north and two south of equator.
9	10 15	1	2	2	"	
10	2 45	0	0	3 gr.	C.R.W.	Large group of faculæ near E. limb.
13	0 0	0	0	1 gr.	"	
17	12 45	1	3	1 gr.	"	Large group of faculæ 1-5 way across disk. Faint aurora at 10 P. M.
20	12 45	1	6	1 gr.	H.C.W.	Two large spots with large area of faculæ.
21	2 30	0	0	0	C.R.W.	Definition poor.
23	2 30	0	0	0	"	
25	12 40	0	0	1 gr.	H.C.W.	Faculæ near S. W. limb.
27	2 05	0	0	"	C.R.W.	" " " " .
30	9 45	0	0	0	"	
31	11 15	1	4	0	H.C.W.	Group in north latitude about 1/3 way across.
Feb. 1	12 50	1	4	1	C.R.W.	
5	12 25	0	0	1 gr.	"	
6	9 30	0	0	1 gr.	"	
7	9 30	0	0	2 gr.	H.C.W.	
8	12 30	0	0	1gr. E	C.R.W.	
11	4 45	0	0	3	H.C.W.	Aurora, faint low arch, noticed from 8 to 10 P. M.
13	4 30	0	0	1 NE	"	
14	12 15	0	0	1gr. SW	"	
15	12 30	0	0	"	C.R.W.	
18	12 30	0	0	2 gr. W	"	
20	12 30	1	1	1 gr.	"	Faint spot near center.

Knowledge for February 1890, contains a beautiful photo-engraving of a remarkable sunspot, photographed by Dr. Jannsen at Meudon, France. This photograph shows a great deal of detail in the penumbra of the spot and in the granulation of the general surface of the sun. But we can hardly subscribe to Mr. Ranyard's astonishing statement that "Our en-

larged copy shows as much as can be seen under the best conditions with the eye at the telescope; and the negative from which it is made shows still more." The copy before us, which seems to be a very perfect one, certainly shows nowhere near what can be seen with our eight-inch refractor under fair conditions, even with the aperture reduced to two inches.

L'Astronomie, Feb. 1890, contains an interesting note in regard to the large spot which appeared upon the sun in June 1889. This spot was observed during three rotations of the sun in June, July and August, disappearing August 20, reduced to a point, before it reached the west limb. On June 28 when the spot was for the first time at the west limb of the sun, Mr. Ricco at Palermo noticed a curious irregularity of the edge of the solar disk, a depression at the spot and one or two elevations on either side. This same irregularity is shown upon the photographs taken the same day at Potsdam. Mr. Ricco determined on each day of observation the exact position of the spot upon the solar disk. When these positions are plotted in latitude and longitude they indicate a curiously irregular course of proper motion of the spot. We hope to give an engraving of this sunspot track in our next number. H. C. W.

Smith Observatory Observations. The following observations of the sun's surface were made with the Brashear Helioscope attached to the 9½ inch equatorial of Smith Observatory. A power of 98 was most commonly used in connection with filar micrometer which Mr. Brashear fitted to the Helioscope.

1890.	90*m* M.T.	Groups.	Spots.	Remarks.
Jan. 20	2	1	4	Seeing fair.
21	1.50	1	4	Seeing poor. Little change: faculæ bright.
23	2	0	0	Seeing very poor. Gran. structure difficult.
24	1.50	0	0	Seeing fair. Faint faculæ near S. E. limb.
27	2	0	0	Seeing good. Gran. st. sharp; no faculæ.
28	2.30	0	0	Seeing fair. No faculæ.
29	2.20	0	0	Seeing fine. Willow leaves visible to limb.*
30	3.50	1	3	Seeing fair. Small and poor. N. lat.
31	2.15	2	5	Seeing fair. Single group div. into two.

Beloit, Wis., Feb. 8, 1890. CHAS. A. BACON.

Smith's Planetary Almanac for 1890 is published by Walter H. Smith, 31 Arcade St., Montreal, Canada. It contains considerable about the planets for each month. Its mailing price is twelve cents per copy.

The Hartford Fire-Ball. December 24 we wrote to Professor R. B. Riggs, of Hartford, Connecticut, concerning the so-called fire-ball which fell in the streets of that city, Dec. 10, as described in the January issue of this journal (p. 40), and asked of him specific information concerning it. In his reply of January 21, he states that he had succeeded in getting a fragment of two or three grams of it, and made a partial chemical analysis of the same. The fragment was wedge shaped, the surface of fracture black, as is the case with igneous rocks containing more or less ferrous iron. The inclined faces were of a light brown,—as might be from exposure

* Transits of willow leaves across micrometer wires were readily taken. Power 221.

and heat. As the owner of the fragment wished to preserve it, the analysis was made from about .8 grams, and was but partial, as follows:

$Ti O_2$	1.60%	$Cr_2 O_3$	none
$Si O_2$	57.37	$Ca O$	trace
$F_3 O$	3.69	$Mg O$	1.57
$Al_2 O_3$	27.24	$K_2 O$	6.50
$Mn O$	none	$Na_2 O$	.93
		Ign	1.05
		Total	99.95

But a fraction of a per cent. was soluble in hydrochloric acid, if any. That the iron was in a ferrous condition was inferred from the action of the rock.

Professor Riggs thinks that the presence of Titanic oxide and the high percentage of alkalies are decidedly against its meteoric origin.

Photographic Notes. In *Monthly Notices* for December, Mr. W. E. Wilson suggests a method of recording the transits of stars by photography. He writes, "If a sensitive photographic plate is placed in the focus of a transit instrument close behind the wires, and the image of a star of suitable magnitude allowed to transit across it, the result is a straight black line on developing the plate. If instead of having the plate fixed, we have it so arranged that it can be given a small up and down motion each second, the result on the plate is a broken line, the breaks in which are equal to seconds of time. The motion is given to the plate by an electro-magnet driven by a current sent by the observatory clock. During or after the transit a light from a small electric lamp is allowed to fall through the object-glass on the plate for a few seconds. This gives an impression of the wires superposed on the star transit. With a rough apparatus I find the time of transit can be recorded to ¼ second, and I believe with some care the time could be taken to a very small fraction of a second."

Professor Holden makes the following statement in regard to stellar photography. "It is possible to get excellent definition with a portrait lens over an area of 25 square degrees, and at least tolerable definition can be obtained over 100 square degrees. If the lens is of 6 or 8 inches aperture stars of the 12th, 13th, or even 14th magnitude can be registered without going to excessively long exposures."

The Photographic Times of January 31 publishes the following in regard to Mr. Burnham's work during the eclipse of last December. "Professor S. W. Burnham arrived in New York from his southern expedition to observe and photograph the eclipse, Wednesday night, January 22d. * * * Of the twelve exposures made during the eclipse, twelve good negatives have been secured. Professor Burnham made also a large collection of negatives of the characteristic life and scenery in Cayenne, as well as on many islands of the West Indies."

Anuario del Observatorio Astronomico National de Taycubayo for the year 1890 has been received. It is the 10th annual of the national Observatory of Mexico, but being in Spanish we can not say much about its contents.

NEWS AND NOTES.

Three important articles are necessarily set over this month, because of unexpected delay in procuring needful cuts to illustrate them. Our engraver has met with serious loss by fire.

Our readers will be interested in the notes from Lick Observatory this month, because of the discoveries announced. Dr. Wilson's article on Lexell's comet adds other features to its study that will attract the attention of American astronomers.

Pioneer Time Service by Observatories. Astronomers and time keepers in Observatories will find interesting reading in a late number of *The Jeweller's Circular and Horological Review* (pp. 82-88), in an article by Lieut. Hiero Taylor, U. S. Navy (in charge of the Government Time Service), under the title of "U. S. Government system of Observatory time." We will notice one point only. Speaking of the history of the time service in this country it is said: "The Naval Observatory was the pioneer in the distribution of time. Other Observatories have since made it a part of their work, and have given, so far as is known, satisfaction to the localities of which they are time centers. In a number of cases they make use of the system which has been adopted by the Naval Observatory, etc." These statements are very erroneous and misleading. By what authority are they published?

Statistics on Observatory Time Service. A few weeks ago, a circular letter asking for facts pertaining to time service was addressed to all, or nearly all, of the Observatories in the United States. The Diıectors of twenty-one Observatories have already responded giving the desired information from all sources that are especially concerned in the present discussion of Observatory local patronage. It is our belief that it is now time to go straight forward in the speedy settlement of this question on its merits at any cost.

Observatory Local Patronage. We have received a number of interesting statements from those in charge of Observatories depending more or less on their local patronage, which plainly show how they are being affected by the tri-partite arrangement between the U. S. Naval Observatory, the Self-Winding Clock Company, and the Western Union Telegraph Company. For want of space we now give but two instances:

Professor G. W. Hough says: "The Dearborn Observatory maintained a time-service in Chicago for many years, receiving therefrom a considerable annual revenue. Two years ago, the Western Union Telegraph Company so interfered with the Observatory service as to practically destroy all revenue. During the past year the service is entirely discontinued."

From a full and concise statement of Assistant F. W. Very, of Allegheny Observatory, we extract a few sentences, as follows: "The value of

the astronomical instruments employed almost exclusively in time Observations may be put down as $7,500." "The compensation (for time-service has) been, and is now more than ever, the main support of the Observatory, which, without it, would probably be obliged to discontinue its work of original research."

Rotation Period of Jupiter's Red Spot. I obtained my last observation of Jupiter, for this season, on the afternoon of November 26, when, however, the seeing was far from good. Low altitude of the planet and air undulations affected the distinctness of the view, but the red spot was seen to be central at about 3^h 54^m. Comparing this with my first observation this year on May 21 at 12^h 31^m I find the mean rotation period 9^h 55^m $40^s.15$ during the interval of 188.64 days. This corresponds very nearly with the period derived from observations here in 1888, which gave 9^h 55^m $40^s.2$ and proves that the velocity of the spot has remained at a pretty uniform rate during the last two years. The same remark applies to 1887 when I found the rate 9^h 55^m $40^s.5$.

Some of the white equatorial spots are still visible but definition has been rarely good enough to afford satisfactory views of these and other details. The large double belt N. of the equator has shown some curious bright spots and irregularities. The latter appears to rotate in a period very slightly less than that of the red spot though somewhat similar markings just S. of the equator move much quicker. For the latter I found a period of 9^h 50^m 6^s in the autumn of 1880, but subsequent observations proved these spots to be slackening in speed. In 1887 Mr. A. Stanley Williams observed many of them and derived a mean period of 9^h 50^m $22^s.4$.

I have seen a drawing of Jupiter made on September 5 last, by Mr. Keeler with the great Lick refractor, power 315. This drawing is certainly the best and the most replete with detail, of any I have ever seen of this planet. It furnishes ample proof of the defining properties of the 36-inch lens and encourages the hope that much useful work will be done on the planets with this noble instrument. W. F. DENNING.

Bristol, December 14, 1889.

Professor W. Upton, of Brown University, Providence, R. I., is to have a new 12-inch equatorial. We are informed that Mr. George A. Saegmuller, Washington, D. C., has the contract for it. With Professor Howe's 20-inch telescope and a number of other smaller orders on hand, Mr. Saegmuller finds his shop room too small, and is therefore adding a new building for increased facilities.

Mr. William Ireland, San Francisco, California, recently sent us two beautiful positives of the total solar eclipse of January 1, 1889, photographed by himself at Norman. The negative from which they were made was a Carbutt No. 27 plate exposed ten seconds. The lens was a large portrait objective No. 7206, Willard & Co., N. Y., with 5¾ inches aperture, stopped down to 3⅞ inches, with back focus about 20 inches.

Both positives are from the same negative, and are developed so that one shows the inner corona to the best advantage, and the other the outer

streamers. This portrait lens has since been purchased by the Lick Observatory and was taken to Cayenne, South America, by the Lick observers for use in photographing the eclipse of Dec. 22. As Mr. Ireland suggests it may be interesting to compare the negatives by this instrument made at both eclipses.

Observations of Meteors on Nov. 26 and 27, 1889. I arranged with five other observers in different parts of England to maintain a watch for meteors on these dates in the hope of seeing a few of the *Andromedes* should any be visible. The weather fortunately proved clear, though bright moonlight offered some impediment to the observations. A number of meteors were recorded by the various observers and the paths were re-projected and discussed by Professor A. S. Herschel who found that very few, if any, belonged to the display from Biela's comet. Some early members of the *Geminid* shower were observed from the point 90°+28° and there was a pretty condensed radiant in Eridanus at 57°—9°. A few of the meteors seen appear to have been *Taurids* and there was scattered radiation from about the point 37°+33°. The latter may have included a few of the *Andromedes* and a few meteors from a shower previously seen by me on Nov. 30, Dec. 7, 1885, at 31°+37° near *β Trianguli.* As to the display of *Leonids* nothing was seen of it this year in England owing to cloudy weather. W. F. DENNING.

Bristol, December 14, 1889.

The Constant of Gravity. Proposition. The space through which a body near the surface of the earth, *in vacuo*, at mean latitude, descends by virtue of the ascending force of gravity is very precisely equal to 2,500 geometric inches = 100 polar cubits = the side of a square geometric acre in $\frac{1}{1000}$ of an hour; thus:

Time in thousandths of an hour.	Acquired velocity. Cubits.	Square of the time.	Total Descent. Cubits.	Difference of squares.	Descent in separate intervals of time. Cubits.
1	200	1	100	1	100
2	400	4	400	3	300
3	600	9	900	5	500
4	800	16	1600	7	700
5	1000	25	2500	9	900
6	1200	36	3600	11	1100
7	1400	49	4900	13	1300
8	1600	64	6400	15	1500
9	1800	81	8100	17	1700
10	2000	100	10000	19	1900

	Cubits.	Acre sides.
So that in $\frac{1}{10000}$ of an hour, total descent =	1 =	$\frac{1}{100}$
" $\frac{1}{1000}$ " " " " " =	100 =	1
" $\frac{1}{100}$ " " " " " =	10000 =	100

and so on, in strict decimal relation with the hour-arc and the half-polar axis of the earth. I. M. C.

Death of Professor C. S. Lyman. We are pained to learn of the death of Professor Chester Smith Lyman, one of the oldest of the professors of Yale University, which occurred Jan. 29, 1890, at his residence in New Haven. He was born in Manchester, Conn., Jan. 13, 1814; entered Yale college 1833; graduated in 1837; superintended the Ellington school for two years; entered Union Theological Seminary, New York, in 1839; was in the theological department of Yale College in 1840; afterwards pastor at New Britain, Conn.; health failing, made a voyage to the Sandwich Islands, and was at Honolulu in 1846. There he taught the Royal school with Queen Emma as a student, who, when in this country later, visited New Haven to see her old teacher. In 1847 he was in California; in 1848 visited the first scene of the gold discovery at Sutter's mill.

In 1850 he came to New Haven, and pursued scientific studies and aided in revising Webster's Dictionary; in 1857, he was appointed Professor of Astronomy and Physics in the Scheffield school; in 1871, he constructed an apparatus for describing acoustic curves and made improvements in clock escapements, compensating pendulums and other apparatus. He was the first to observe the luminous ring about the planet Venus when at inferior conjunction. After 1859 he was a number of years president of the Connecticut Academy of Science, and in 1870 he was elected honorary member of the British Association for the advancement of science. Professor Lyman retained his position in the chair of Astronomy and Physics in the Yale Scientific School until the time of his death, although on account of ill health he was long unable to perform its full duties.

Yale University Observatory. Part II of Vol. I of the Transactions of the Astronomical Observatory of Yale University is an interesting paper prepared by Asaph Hall, Jr., Assistant Astronomer in the Observatory. The subject of the paper is the determination of the orbit of Titan and the mass of Saturn. The instrument used was the Heliometer. The reason for re-determining the orbit of Titan was the difference of result, for the mass of Saturn, obtained by Bessel with the Konigsberg Heliometer, by observing Titan, and that of Professor Hall with the large Washington refractor from observations by Titan and Japetus. The reciprocal of the mass of Saturn's system found by Professor Hall from Japetus, by means of differences of right ascension and declination, was 3481.2, and by distances and position-angles 3481.4; from Titan, the values corresponding to the same methods were 3496.3, and 3469.9. The value found, as shown in this paper, is 3500.5 ± 1.44, and the writer thinks there is ground for questioning the results obtained from observations by the large refractor at Washington. The mass obtained for Saturn as given by Chambers' Handbook (last edition) by different authorities is interesting for comparison. Newton, 3021; Laplace, 3359; Bouvard, 3512; Bessel, 3500.5; Jacob, for the Saturnian system, 3475, and A. Hall, 3478. We do not know from what source this last value is taken, as the above paper does not mention it. We also notice that the value for Saturn's mass, as given in Young's General Astronomy, is 3490. The Yale value of the mass of Saturn's system is seen to be most nearly in accord with Bessel's given above, and Struve's, which is 3500.2 by Japetus, and 3495.7 by Titan.

Erratum. In the Sidereal Messenger for February, page 82, the masses of the components of β Aurigae are given as 0.1 or 0.2, owing to error in writing out the results of the computation, which showed, in fact, that the sum of the masses should be 2.3.

BOOK NOTICES.

Elements of Differential and Integral Calculus with Numerous Examples. By T. A. Smith, Professor of Mathematics and Physics in Beloit College, Beloit, Wis. 1889, pp. 140.

This new book presents a brief course in the Calculus, prepared on a plan to enable a student to acquire a working knowledge of the elements of the subject, in as brief a time as possible. It does not claim to be original, except in its condensed form, and in the range of its applications.

The range of subjects which this small book presents is about that found in elemental works on the same subject having three or four times its size. It seems to us that the different subjects are too much condensed for the beginner to make much headway without large help from a teacher, in the way of additional explanation. The matter is good, but has the author left room by its gradation and arrangement for the student to work independently enough for his own best and most rapid advancement? Give the young mind a clear and firm grasp of principle, and then try its powers in varied application severely; make the student tired, judiciously, in doing hard things which the teacher knows he has mastered before he leaves him, to secure growth and strength of mind. We are sorry to see so poor and inaccurate a sample of printing. We hope the author will not leave the work as it now appears, but raise it to a standard of excellence easily within his ability to do, as compared with other late works on the same subject.

An Elementary Treatise upon the Method of Least Squares, with Numerical Examples on its applications. By George C. Comstock, Professor of Astronomy in the University of Wisconsin and Director of the Washburn Observatory. Boston, Messrs. Ginn & Company, 1890, pp. 68.

In this work, the reader is given a new method of treating the subject of Least Squares. It was developed by the author in his attempts to so present the subject to students of physics, astronomy and engineering that a working knowledge, based upon an appreciation of its principles, might be acquired with a moderate outlay of time and labor. We think the author properly claims that the ultimate warrant for the legitimacy of his method is to be found in the agreement between the observed distribution of residuals and the distribution represented by the error curve. For other important reasons the analytical demonstrations of the equation of this curve are abandoned, and it is presented as an empirical formula representing the generalized experience of observers. The discussion of these reasons would lead away from the object of this notice. It may be sufficient to say, that the difficulties which the analytical demonstration present to the attention of students generally prove sufficient to absorb their whole attention, and cause them to lose sight of the purpose for which the analysis is conducted.

The author begins his work with a simple example consisting of four observations only, from which observation equations are formed, with suggestions indicating how other similar ones might be made. In this way he derives two important principles:

1. That the adopted values of the quantities which are to be determined must be based upon *all* the data available. 2. The adopted values must satisfy the observation equations as nearly as possible. Then follow the consideration of the following topics: Errors and Residuals, The Distribution of Residuals, The Error Curve, The principles of Least Squares, Weights, Normal Equations, Forming and Solution of Normal Equations, Numerical Examples, Probable Error of a Function of Observed Equations, Assignment of Weights, Rejection of Observations, Empirical or Interpolation Formulæ, Approximate Solutions and Index to Formulæ.

This is a carefully prepared work, and, in our judgment, it presents the subject of Least Squares in the simplest and most direct way to meet the wants of nine-tenths of those desiring to acquire a knowledge of its principles for practical uses. Those who would master the theoretical side of the theme will find in a number of accessible treatises abundant room for vigorous mental exercise. The neat typography of this book is a credit to all who have had to do with its mechanical finish.

New Plane and Solid Geometry. Revised Edition. By G. A. Wentworth, A. M., Professor of Mathematics in Phillips Exeter Academy. Boston, Messrs. Ginn & Company, Publishers, 1889. pp. 437.

The first edition of Wentworth's Geometry was published about thirteen years ago. Since that time, the book has been in such favor that large editions have been printed every year, and the increasing demand for the book has recently brought out a new edition, the copy of which has been wholly rewritten. Several points of a minor kind appear, here and there, throughout the book, suggested by the experience of some of the best teachers of Geometry in this country. The addition of 700 exercises to this edition is a feature that the instructor will quickly notice. This is an excellent book for the class-room.

A College Algebra. By J. M. Taylor, A. M., Professor of Mathematics in Madison University. Boston: Messrs. Ally & Bacon Publishers, 1889, pp. 317. Introductory Price $1.50.

This book on Algebra is divided into two parts, the first consisting of eleven chapters covering 121 pages, and embracing about the usual amount of Algebra to enter College. The second part is presented in ten chapters having the following titles: Functions and Theory of Limits, Differentiation, Development of Functions in Series, Convergency and Summation of Series, Logarithms, Compound Interest and Annuities, Permutations and Combinations, Probability, Continued Fractions and Theory of Equations.

It will be observed at a glance that the second part of this Algebra treats many of the above subjects by the later and by far the best methods, and many instructors decidedly prefer the methods of limits, so-called, to that of infinitesimals, as a mode of explaining the fundamental operations of this delightful analysis. Although we do not, we are glad to see an Algebra that gives the next best thing, for there are so many late books on this branch that hold to old methods that we sincerely wonder if they will ever be entirely given up. This book is commended to the attention of teachers.